NORTH CAROLINA
Department of Transportation

Technical Services – Hydraulics Unit

Preconstruction Workshop

May 16-17th, 2023

What we do…

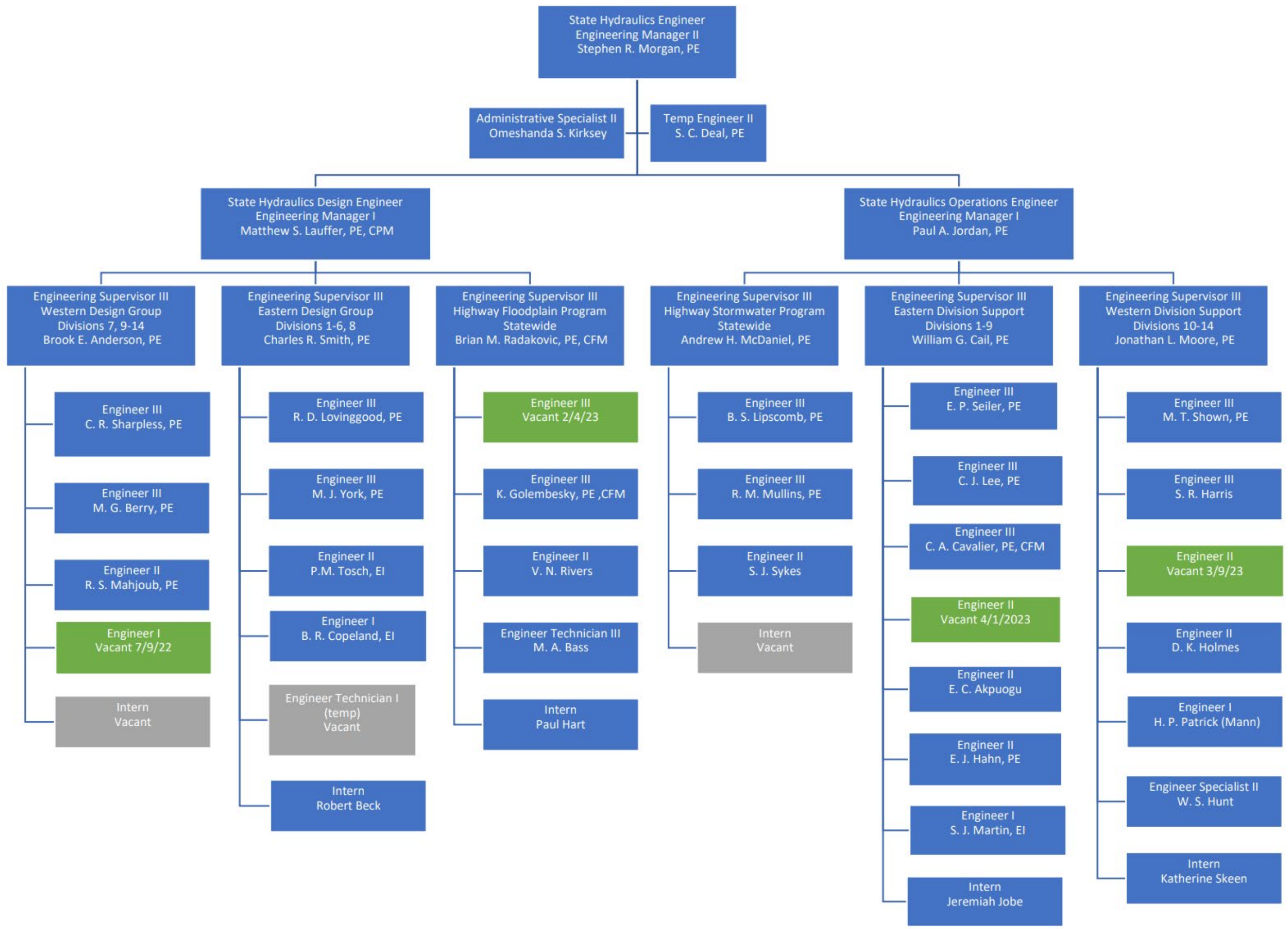
The Hydraulics Unit provides the Department and State partners with transportation water management services for planning, design, operations, and construction.

Groups In Hydraulics Unit

- Design
- Operations
- Floodplain Program
- Stormwater Program

HYDRAULICS UNIT

ORGANIZATION CHART



Hydraulics Unit Organization

- State Hydraulics Engineer- Stephen Morgan
- State Hydraulics Design Engineer- Matt Lauffer
  - TIP Designs
  - Resilience
  - Storm Operations
  - DB support
  - Guideline support
  - ORD Development
- Engineering Supervisor, East – Charles Smith
- Engineering Supervisor, West - Brook Anderson

Hydraulics Unit Organization

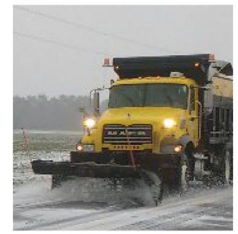
- State Hydraulics Operations Engineer- Andy Jordan
  - Express Design
  - Emergency Design
  - Encroachments/Subdivisions
  - Tort claims/ expert witness
  - Storm Response and Recovery
- Engineering Supervisor, East - Galen Cail
- Engineering Supervisor, West - Jon Moore

Hydraulics Unit Organization

- Highway Floodplain Program- Brian Radakovic
  - FEMA compliance
  - Hydraulic data archives
  - Guideline support
  - Storm Planning, Response, Recovery
  - Modeling
  - Resilience
- Highway Stormwater Program- Andy McDaniel
  - NPDES compliance
  - Stormwater Retrofits
  - Research
  - BMP Toolbox
  - Section 401 Certification Negotiation Support

NORTH CAROLINA
Department of Transportation



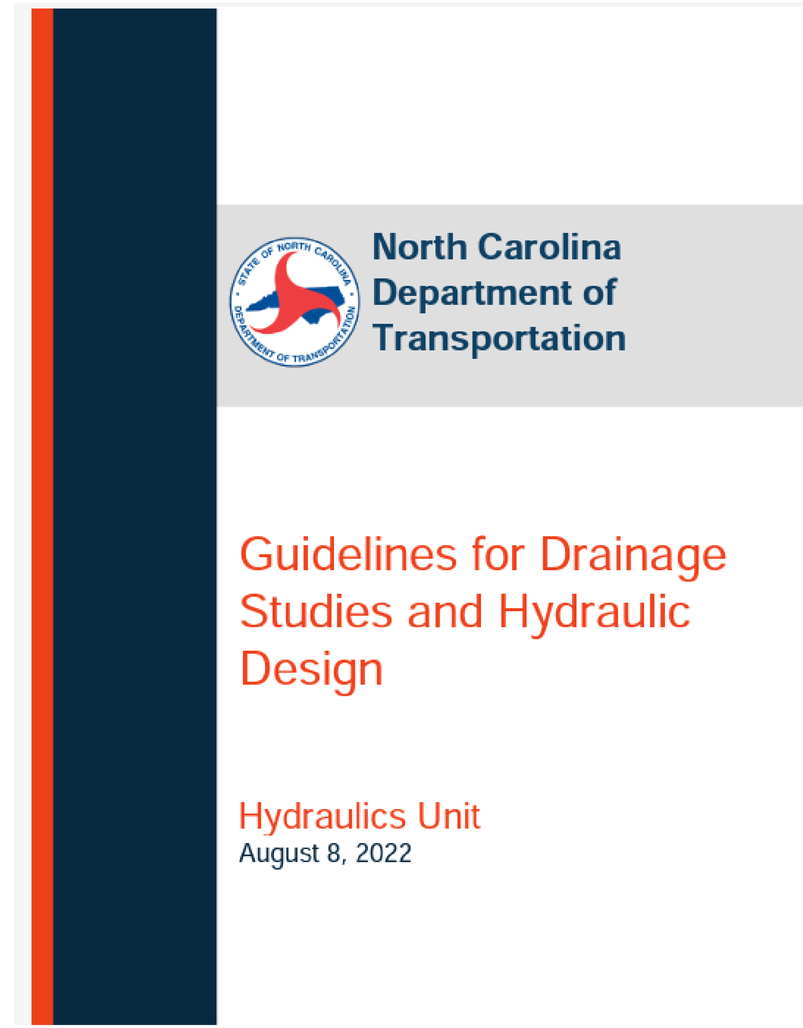

2023 Hydraulics State of Practice

Guidelines for Drainage Studies and Hydraulic Design

Objective

To develop a detailed "roadmap" for comprehensive update of the collective Hydraulics Unit's library of documents, and to make recommendation to transition the library to more of a "living document" format subject to a cycle of continuous improvement. Tasks included:

- ❖ Review of Existing Guidance, Protocol and Manuals
- ❖ Detailed Survey to Identify Critical Gaps and Needs in the Existing Guidance; Also Identify any Research or Emerging Technology to Help Improve Guidance
  - ➢ NCDOT Staff
  - ➢ State Agencies
  - ➢ Municipal and Academic
  - ➢ Private Engineering Consultants
- ❖ Review of Peer Agencies Documentation for Critical Gaps
- ❖ Ties into the overall Project Delivery Network (PDN)
- ❖ 2022 update is considered a "light" update that re-organizes the Guidelines to better align with the PDN.


North Carolina Department of Transportation

Guidelines for Drainage Studies and Hydraulic Design

Hydraulics Unit
August 8, 2022

Design Support

- In-house design
- IPD
  - QC/QA checklists
- Drainage design review

PDN Stage 2HY2 – Hydraulics QA Checklist

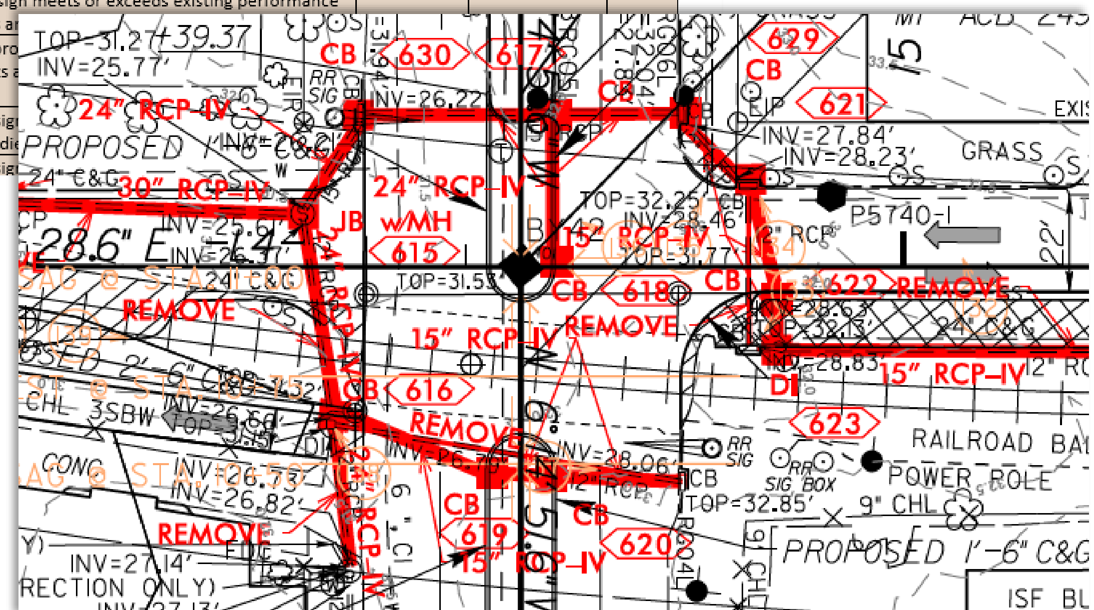
SPOT ID/Project TIP #: Click to edit.

County: Click to edit.

2HY2: Drainage Design for Field Inspection

Deliverable: Hydraulic Survey Reports for Major Structures

AA #	1	Structure Design - General	Acceptable	Unacceptable	N/A
	1.1	QC procedures have been followed and are complete	☐	☐	☐
	1.2	Structure design conforms to agreed design assumptions and direction from Hydraulics Pre-Design Meeting			
	1.3	Structure design meets or exceeds existing performance and provides ar			
	1.4	For Merger pro commitments a CP4B			
	1.5	Drainage desig Drainage Studi			
		Drainage desig			



Design Support

- Standard Specifications 2024
- ORD
- Hydroplaning Analysis
- MSE Wall Drainage Guideline Development
- Outlet Analysis Tool Development
- Hydraulic Planning Report Development
- Sea Level Rise
- New Rainfall Design Development

NCDOT Standard Specifications 2024 Changes

300-6: HDPE and Polypropylene permitted on steep slopes when mechanical couplers are used:

(B) Flexible Pipe

Corrugated steel, corrugated aluminum, polypropylene, HDPE and PVC pipe will be considered flexible pipe. Place flexible pipe carefully on the prepared foundation starting at the downstream end with the inside circumferential laps pointing downstream and with the longitudinal laps at the side or quarter points.

Handle coated corrugated steel pipe with special care to avoid damage to coatings.

Join corrugated steel and corrugated aluminum pipe sections with coupling band, fully bolted and properly sealed. Provide coupling bands for annular and helical corrugated metal pipe with circumferential and longitudinal strength sufficient to preserve the alignment, prevent separation of the sections and prevent backfill infiltration. Match-mark all pipe 60 inches or larger in diameter at the plant for proper installation on the project.

Only at locations with rod and lug connectors indicated in the plans, join corrugated steel pipe sections together with rod and lug coupling bands, fully bolted. Use sleeve gaskets in conjunction with rod and lug couplings and seal the joints properly.

For HDPE, polypropylene, and PVC pipe use a gasketed bell and spigot connection where not otherwise specified in the plans.

Only at locations with couplers indicated in the plans, join HDPE and polypropylene pipe sections together with coupling bands. Provide coupling bands with circumferential and longitudinal strength sufficient to preserve the alignment, prevent separation of the sections and prevent infiltration of backfill material.

300-7 BACKFILLING

Note: Photo is shown for dramatization purposes. Pipes must be buried.

NCDOT Standard Drawings 2024 Changes

300.01 Sheet 3 of 3 eliminated from Std Dwgs, and replaced with Pipe Material Selection Guide

NCDOT PIPE MATERIAL SELECTION GUIDE

FILL TABLES

RCP[1] (REINFORCED CONCRETE) AASHTO M170

CLASS II MIN.[4]	CLASS II MAX.	CLASS III MIN.[4]	CLASS III MAX.	CLASS IV MIN.[4]	CLASS IV MAX.	CLASS V MIN.[4]	CLASS V MAX.
2.0'	10.0'	2.0'	20.0'	1.0'	30.0'	1.0'	40.0'

(FOR FILLS >40' & <80' USE LRFD DIRECT DESIGN METHOD. NOTE: DIRECT DESIGN METHOD RCP PIPES MUST HAVE A MINIMUM DIAMETER OF 36".)

WHEN FILL HEIGHTS (NOT INCLUDING THE PAVEMENT STRUCTURE AND CURB) FOR RCP RUNNING PARALLEL TO AND UNDER CURB AND GUTTER, EXPRESSWAY GUTTER, SHOULDER BERM GUTTER AND ADJACENT TO MEDIAN BARRIER ARE 1' OR LESS, SPECIFY CLASS IV RCP.

WHEN THE FILL HEIGHTS (FROM TOP OF PIPE TO SUBGRADE) FOR RCP RUNNING UNDER/ACROSS THE PAVEMENT ARE 1' OR LESS, SPECIFY CLASS V RCP.

SPECIFY A SINGLE CLASS OF RCP IN A SINGLE RUN OF PIPE.

CSP[2] (CORRUGATED STEEL) AASHTO M36 2 ⅔ X ½ CORRUGATION[3]

SIZE	MIN.[4]	MAXIMUM (Ga) 16	14	12	10	8
12"	1.0'	204'	256'			
15"	1.0'	162'	204'			
18"	1.0'	135'	169'	239'		
24"	1.0'	100'	126'	178'		
30"	1.0'	79'	100'	142'		
36"	1.0'	65'	83'	117'	152'	
42"	1.0'	55'	70'	100'	130'	160'
48"	1.0'	48'	61'	87'	113'	139'
54"	1.0'		54'	77'	100'	123'
60"	1.0'			69'	90'	111'
66"	1.0'				81'	100'
72"	1.0'				74'	91'
78"	1.0'					81'
84"	1.0'					69'

CAAP (CORRUGATED ALUMINUM) AASHTO M196 2 ⅔ x ½ CORRUGATION[3]

SIZE	MIN.[4]	MAXIMUM (Ga) 16	14	12	10	8
12"	1.0'	123'	155'	218'	281'	344'
15"	1.0'	98'	123'	174'	224'	275'
18"	1.0'	81'	102'	144'	187'	228'
24"	1.0'	60'	76'	108'	139'	171'
30"	1.0'		60'	85'	111'	136'
36"	1.0'		50'	71'	92'	113'
42"	1.0'			60'	78'	96'
48"	1.0'			52'	68'	84'
54"	1.0'			46'	50'	74'
60"	1.0'				50'	62'
66"	1.0'					51'
72"	1.0'					41'

HDPE AASHTO M294 SIZE	MIN.[4]	MAX.	PP[7] ASTM F2881, ASTM F2764, OR AASHTO M330 SIZE	MIN.[4]	MAX.	PVC–ASTM F949 AASHTO M304 SIZE	MIN.[4]	MAX.
12"	2.0'	20'	12"	1.0'	20'	12"	2.0'	30'
15"	2.0'	20'	15"	1.0'	20'	15"	2.0'	30'
18"	2.0'	20'	18"	1.0'	20'	18"	2.0'	30'
24"	2.0'	20'	24"	1.0'	20'	24"	2.0'	30'
30"	2.0'	17'	30"	1.0'	20'	30"	2.0'	30'
36"	2.0'	17'	36"	1.0'	20'	36"	2.0'	30'
42"	2.0'	17'	42"	1.0'	20'			
48"	2.0'	17'	48"	1.0'	20'			
54"	2.0'	17'	54"	NA	NA			
60"	2.0'	17'	60"	1.0'	20'			

		RCP	CSP	CAAP	HDPE / PP / PVC
OPEN END CROSS PIPES	INTERSTATE[5]	CAN BE USED	USE ONLY IF PIPE SLOPE IS GREATER THAN 10%	USE ONLY IF PIPE SLOPE IS GREATER THAN 10%	DO NOT USE
	PRIMARY[5]	CAN BE USED	CAN BE USED	CAN BE USED	USE ONLY IF TRAFFIC <10000 ADT & <200 DUALS & <100 TTST
	SECONDARY	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED
STORM DRAIN SYSTEMS	INTERSTATE	CAN BE USED	USE ONLY AT SYSTEM INLETS & SYSTEM OUTLET IF PIPE SLOPE IS GREATER THAN 10%	USE ONLY AT SYSTEM INLETS & SYSTEM OUTLET IF PIPE SLOPE IS GREATER THAN 10%	DO NOT USE
	PRIMARY	CAN BE USED	USE ONLY AT SYSTEM INLETS & SYSTEM OUTLET IF PIPE SLOPE IS GREATER THAN 10%	USE ONLY AT SYSTEM INLETS & SYSTEM OUTLET IF PIPE SLOPE IS GREATER THAN 10%	USE ONLY IF TRAFFIC <10000 ADT & <200 DUALS & <100 TTST
	SECONDARY	CAN BE USED	USE ONLY AT SYSTEM INLETS & SYSTEM OUTLET IF PIPE SLOPE IS GREATER THAN 10%	USE ONLY AT SYSTEM INLETS & SYSTEM OUTLET IF PIPE SLOPE IS GREATER THAN 10%	CAN BE USED
TRANSVERSE MEDIAN PIPES	INTERSTATE	CAN BE USED	USE ONLY IF PIPE SLOPE IS GREATER THAN 10%	USE ONLY IF PIPE SLOPE IS GREATER THAN 10%	DO NOT USE
	PRIMARY	CAN BE USED	CAN BE USED	CAN BE USED	USE ONLY IF TRAFFIC <10000 ADT & <200 DUALS & <100 TTST
	SECONDARY	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED
SLOPE DRAINS[6]	INTERSTATE	DO NOT USE	CAN BE USED	CAN BE USED	CAN BE USED
	PRIMARY	DO NOT USE	CAN BE USED	CAN BE USED	CAN BE USED
	SECONDARY	DO NOT USE	CAN BE USED	CAN BE USED	CAN BE USED
SIDE DRAINS	INTERSTATE	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED
	PRIMARY	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED
	SECONDARY	CAN BE USED	CAN BE USED	CAN BE USED	CAN BE USED

NOTES

1– RCP IS NOT ALLOWED FOR GRADES >10%
2– FOR COUNTIES LISTED IN ARTICLE 310 OF THE STANDARD SPECIFICATIONS CSP IS NOT ALLOWED. IN OTHER COUNTIES, CSP REQUIRES AN ACCEPTABLE COATING IN ACCORDANCE WITH 1032.
3– FOR DIFFERENT CORRUGATIONS AND ARCH PIPES REFER TO ROADWAY DESIGN MANUAL AND MANUFACTURERS SPECIFICATION.
4– MINIMUM FILL HEIGHT IS MEASURED FROM TOP OF PIPE TO SUBGRADE. MINIMUM COVER IS 1FT WHEN PIPE IS USED AS A SIDE DRAIN.
5– WHERE SITE CONDITIONS ALLOW: INCREASE PIPE DIAMETER OF OPEN END CROSS PIPES AND SECTIONS OF STORM SEWER SYSTEMS ACTING AS OPEN END CROSS PIPES, A MINIMUM OF ONE SIZE FOR FUTURE REHABILITATION. THIS IS IN ADDITION TO UPSIZING TO COMPENSATE FOR BURYING INVERTS FOR WILDLIFE PASSAGE.
6– FOR PIPE RUNS WITH GREATER THAN 12' VERTICAL DROP TO DOWNSTREAM STRUCTURE, PROVIDE A MEANS TO REDUCE RISK OF UNINTENDED ENTRY INTO UPSTREAM END OF PIPE.
7– FILL HEIGHTS SHOWN WERE CALCULATED USING AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS. JUSTIFY FILL HEIGHT OR DESIGN DEVIATIONS WITH STRUCTURAL DESIGN BASED ON AASHTO LRFD BRIDGE DESIGN OR ASTM STANDARDS. SUBMIT DESIGN SEALED BY AN NC PE FOR REVIEW & APPROVAL BY NCDOT.

INSTALLATION OF ALL PIPE TYPES IS SUBJECT TO THE INSTALLATION METHODS FOUND IN THE STANDARD DRAWINGS, STANDARD SPECIFICATIONS, HYDRAULICS GUIDELINES, AND CONTRACT DOCUMENTS; ACCOUNTING FOR SITE CONDITIONS SUCH AS SOIL PROPERTIES.

ALL PIPES TYPES ARE SUBJECT TO THE MAXIMUM AND MINIMUM FILL HEIGHT REQUIREMENTS AS FOUND IN THE ROADWAY DESIGN MANUAL. THE APPROPRIATE CLASS OF PIPE FOR RCP AND GAUGE THICKNESS FOR CSP/CAAP SHOULD BE SELECTED BASED ON FILL HEIGHT.

SITE SPECIFIC CONDITIONS MAY LIMIT A PARTICULAR MATERIAL BEYOND WHAT IS IDENTIFIED IN THE TABLE. THESE CONDITIONS INCLUDE, BUT ARE NOT LIMITED TO, ABRASION, ENVIRONMENTAL, SOIL RESISTIVITY AND PH, HIGH GROUND WATER AND SPECIAL LOADING CONDITIONS. THE HYDRAULIC DESIGN ENGINEER WILL DETERMINE IF ADDITIONAL RESTRICTIONS ARE NECESSARY.

DEFINITIONS

SIDE DRAINS- STORM DRAIN PIPES RUNNING PARALLEL TO THE ROADWAY TO INCLUDE PIPES IN THE MEDIANS, OUTSIDE DITCHES, DRIVEWAYS AND UNDER SHOULDER BERM GUTTER ALONG OUTSIDE SHOULDERS GREATER THAN 4' WIDE. MAY OR MAY NOT BE OPEN ENDED. 1' MINIMUM COVER FOR ALL SIDE DRAIN PIPE IN ACCORDANCE WITH STANDARD SPECIFICATION SECTION 310.

STORM DRAIN SYSTEMS- LATERAL DRAIN PIPE UNDER CURB AND GUTTER, EXPRESSWAY GUTTER AND SHOULDER BERM GUTTER (WITH SHOULDERS 4' WIDE OR LESS) THAT CONNECT DRAINAGE STRUCTURES AND IS NOT OPEN ENDED. ALSO INCLUDES CROSS DRAIN CONNECTING TWO OR MORE SYSTEMS OR SYSTEM OUTLETS. ONLY PIPE WITH SMOOTH INSIDE WALLS WILL BE ALLOWED FOR STORM DRAIN SYSTEMS.

TRANSVERSE MEDIAN PIPES- SHALLOW CROSS DRAIN PIPE THAT COLLECTS DRAINAGE IN A MEDIAN DITCH OR CURB SECTION AND DEPOSITS IT OUTSIDE DITCHES OR NATURAL DRAINAGE CHANNELS. MAY OR MAY NOT BE OPEN ENDED.

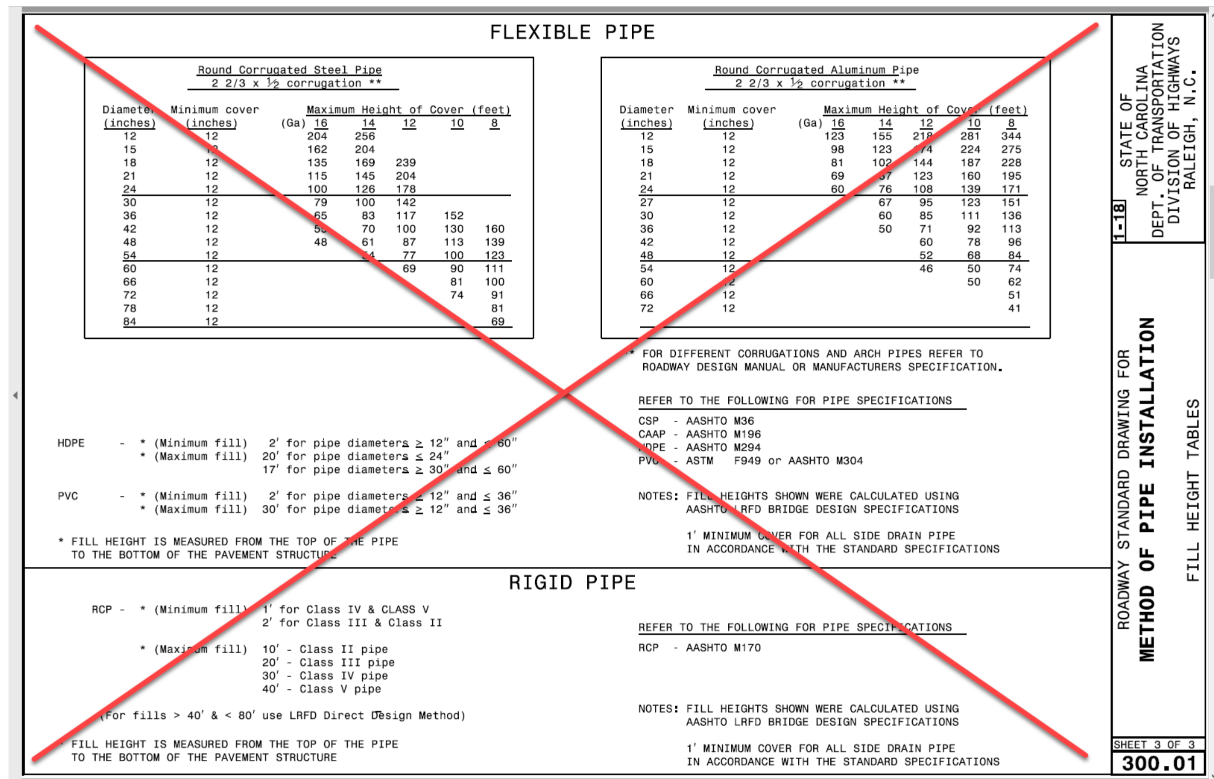
ALTERNATE PIPE- PIPE IN WHICH MATERIAL IS UNSPECIFIED ON THE DRAINAGE SUMMARY SHEET AND DRAINAGE PLANS.

HDPE- HIGH DENSITY POLYETHYLENE

PP- POLYPROPYLENE

Printed 2022 08 25
Revised 2022 08 25

NCDOT_PipeMaterial_Selection_Guide_2022 08 25 revision .dgn Default 8/25/2022 2:18:25 PM



FLEXIBLE PIPE

Round Corrugated Steel Pipe
2 2/3 x ½ corrugation **

Diameter (inches)	Minimum cover (inches)	Maximum Height of Cover (feet) (Ga) 16	14	12	10	8
12	12	204	256			
15	12	162	204			
18	12	135	169	239		
21	12	115	145	204		
24	12	100	126	178		
30	12	79	100	142		
36	12	65	83	117	152	
42	12	55	70	100	130	160
48	12	48	61	87	113	139
54	12		54	77	100	123
60	12			69	90	111
66	12				81	100
72	12				74	91
78	12					81
84	12					69

Round Corrugated Aluminum Pipe
2 2/3 x ½ corrugation **

Diameter (inches)	Minimum cover (inches)	Maximum Height of Cover (feet) (Ga) 16	14	12	10	8
12	12	123	155	218	281	344
15	12	98	123	174	224	275
18	12	81	102	144	187	228
21	12	69	87	123	160	195
24	12	60	76	108	139	171
27	12		67	95	123	151
30	12		60	85	111	136
36	12		50	71	92	113
42	12			60	78	96
48	12			52	68	84
54	12			46	50	74
60	12				50	62
66	12					51
72	12					41

** FOR DIFFERENT CORRUGATIONS AND ARCH PIPES REFER TO ROADWAY DESIGN MANUAL OR MANUFACTURERS SPECIFICATION.

REFER TO THE FOLLOWING FOR PIPE SPECIFICATIONS

CSP - AASHTO M36
CAAP - AASHTO M196
HDPE - AASHTO M294
PVC - ASTM F949 or AASHTO M304

HDPE - * (Minimum fill) 2' for pipe diameters ≥ 12" and ≤ 60"
* (Maximum fill) 20' for pipe diameters ≤ 24"
17' for pipe diameters ≥ 30" and ≤ 60"

PVC - * (Minimum fill) 2' for pipe diameters ≥ 12" and ≤ 36"
* (Maximum fill) 30' for pipe diameters ≥ 12" and ≤ 36"

* FILL HEIGHT IS MEASURED FROM THE TOP OF THE PIPE TO THE BOTTOM OF THE PAVEMENT STRUCTURE

NOTES: FILL HEIGHTS SHOWN WERE CALCULATED USING AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS

1' MINIMUM COVER FOR ALL SIDE DRAIN PIPE IN ACCORDANCE WITH THE STANDARD SPECIFICATIONS

RIGID PIPE

RCP - * (Minimum fill) 1' for Class IV & CLASS V
2' for Class III & Class II

* (Maximum fill) 10' - Class II pipe
20' - Class III pipe
30' - Class IV pipe
40' - Class V pipe

(For fills > 40' & < 80' use LRFD Direct Design Method)

* FILL HEIGHT IS MEASURED FROM THE TOP OF THE PIPE TO THE BOTTOM OF THE PAVEMENT STRUCTURE

REFER TO THE FOLLOWING FOR PIPE SPECIFICATIONS

RCP - AASHTO M170

NOTES: FILL HEIGHTS SHOWN WERE CALCULATED USING AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS

1' MINIMUM COVER FOR ALL SIDE DRAIN PIPE IN ACCORDANCE WITH THE STANDARD SPECIFICATIONS

STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

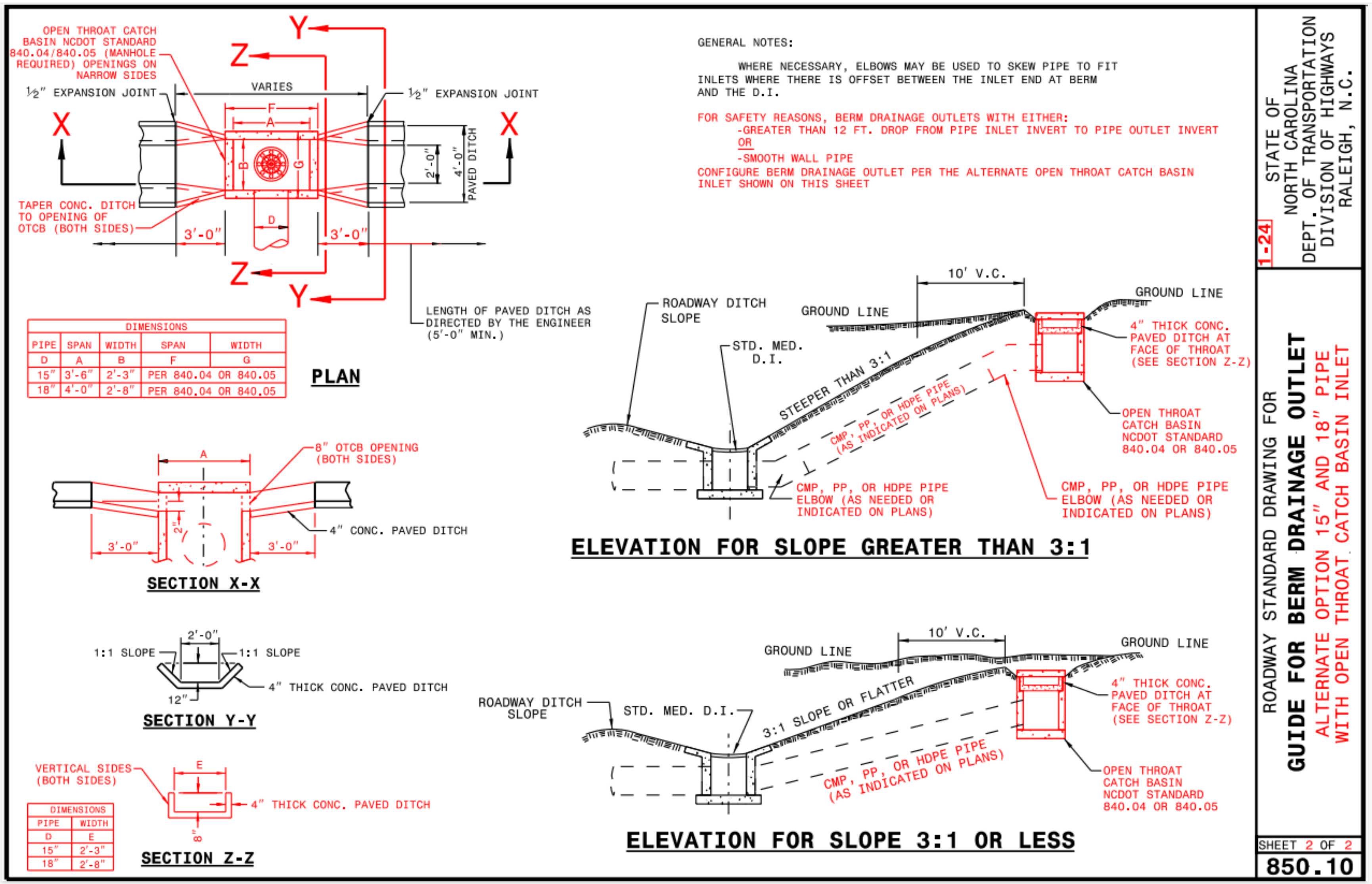
1-18

ROADWAY STANDARD DRAWING FOR
METHOD OF PIPE INSTALLATION
FILL HEIGHT TABLES

SHEET 3 OF 3
300.01

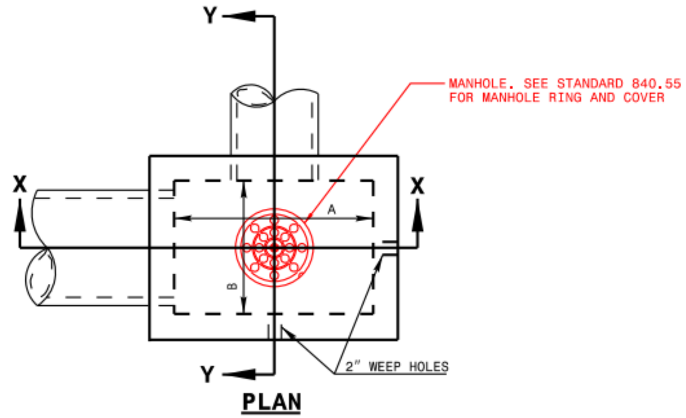
NCDOT Standard Drawings 2024 Changes

850.10 & 850.11 Berm Drainage Outlet



NCDOT Standard Drawings 2024 Changes

840.04 OTCB: Manhole Access Added



NOTES: USE CLASS "B" CONCRETE THROUGHOUT.

PROVIDE ALL CATCH BASINS OVER 3'-6" IN DEPTH WITH STEPS 12" ON CENTER. USE STEPS WHICH COMPLY WITH STD. DRAWING 840.66.

USE #4 BAR DOWELS AT 12" CENTERS

USE FORMS FOR THE CONSTRUCTION OF THE BOTTOM SLAB.

IF REINFORCED CONCRETE PIPE IS SET IN BOTTOM SLAB OF BOX, ADD TO SLAB AS SHOWN ON STD. NO. 840.00.

FOR 8'-0" IN HEIGHT OR LESS USE 6" WALLS AND BOTTOM SLAB. OVER 8'-0" TO 16'-0" IN HEIGHT USE 8" WALLS AND BOTTOM SLAB. ADJUST QUANTITIES ACCORDINGLY.

MAX. DEPTH OF THIS STRUCTURE FROM TOP OF BOTTOM SLAB TO TOP ELEVATION IS 16 FEET. STD. DWG. 840.45 OR 840.46 CONTROLS MAX. DEPTH IF PRECAST BOX IS USED.

CONSTRUCT WITH PIPE CROWNS MATCHING.

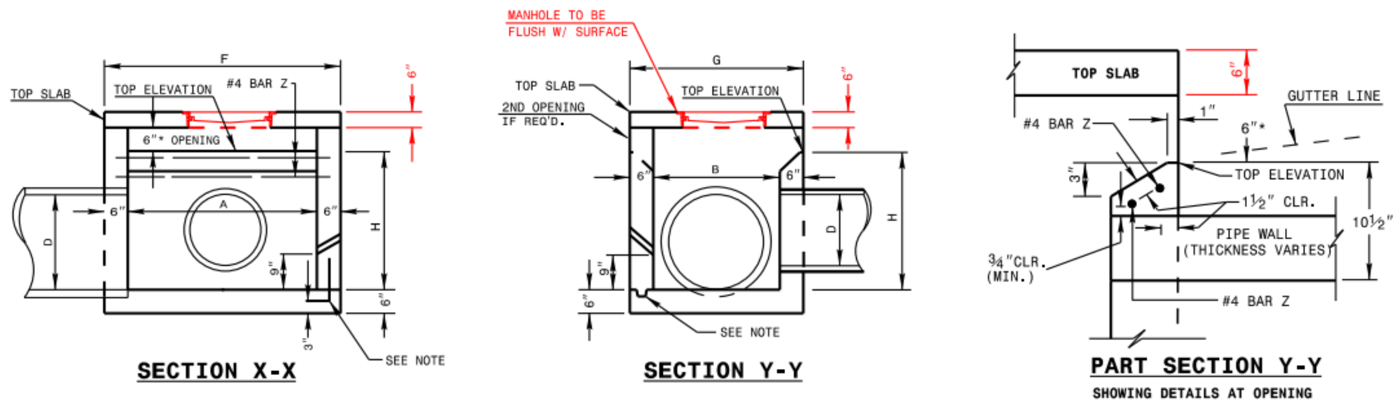
INSTALL 2" WEEPHOLES AS DIRECTED BY THE ENGINEER.

INSTALL STONE DRAINS, OF A MINIMUM OF 1 CUBIC FOOT OF NO. 78M STONE IN A POROUS FABRIC BAG OR WRAP, AT EACH WEEP HOLE OR AS DIRECTED BY THE ENGINEER.

CHAMFER ALL EXPOSED CORNERS 1".

DRAWING NOT TO SCALE.

* INCREASE THE SIZE OF THE 6" OPENING TO 8" MAX., AS DIRECTED BY THE ENGINEER BY ADDING 2" TO THE WALL HIEGHT ABOVE THE TOP ELEVATION. ADJUST QUANTITIES ACCORDINGLY.



MIN. DIMENSIONS AND QUANTITIES FOR CONCRETE CATCH BASIN (BASED ON MIN. HEIGHT, H)

DIM'S OF BOX & PIPE				REINFORCING								TOP & BOT. SLAB DIMENSIONS		CU. YDS. CONC. IN BOX			TOTAL QUANTITIES BOX & SLABS		DEDUCTION ONE PIPE		DED. ONE 6" THROAT OPENING
PIPE	SPAN	WIDTH	HEIGHT	BARS - W		BARS - X		BARS - Y		BARS - Z											
D	A	B	H	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	NO.	LENGTH	F	G	TOP SLAB	BOT. SLAB	WALL/FT. HT.	LBS. REINF.	YD³ (MIN H)	C.S.	R.C.	YD³
12"	3'-6"	2'-3"	1'-10"	8	3'-8"	4	3'-0"	6	4'-3"	2	4'-3"	4'-6"	3'-3"	0.207	0.271	0.250	47	1.046	0.015	0.032	0.046
15"	3'-6"	2'-3"	2'-1"	8	3'-8"	4	3'-0"	6	4'-3"	2	4'-3"	4'-6"	3'-3"	0.207	0.271	0.250	47	1.108	0.023	0.036	0.046
18"	4'-0"	2'-8"	2'-4"	8	5'-0"	5	3'-5"	7	4'-9"	2	4'-9"	5'-0"	3'-8"	0.275	0.340	0.284	61	1.379	0.033	0.049	0.053
24"	4'-0"	2'-8"	2'-10"	8	5'-0"	5	3'-5"	7	4'-9"	2	4'-9"	5'-0"	3'-8"	0.275	0.340	0.284	61	1.521	0.059	0.085	0.053
30"	4'-0"	3'-6"	3'-4"	8	6'-2"	5	4'-3"	9	4'-9"	2	4'-9"	5'-0"	4'-6"	0.353	0.417	0.315	77	1.916	0.092	0.127	0.053
36"	4'-6"	4'-0"	3'-10"	8	7'-7"	5	4'-9"	10	5'-3"	2	5'-3"	5'-6"	5'-0"	0.445	0.510	0.352	94	2.390	0.132	0.178	0.059
42"	5'-0"	4'-6"	4'-4"	8	9'-0"	5	5'-3"	12	5'-9"	2	5'-9"	6'-0"	5'-6"	0.547	0.611	0.389	119	2.914	0.180	0.243	0.066
48"	5'-0"	5'-0"	4'-10"	8	9'-8"	5	5'-9"	13	5'-9"	2	5'-9"	6'-0"	6'-0"	0.603	0.666	0.407	128	3.298	0.235	0.317	0.066

STATE OF NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

1-24

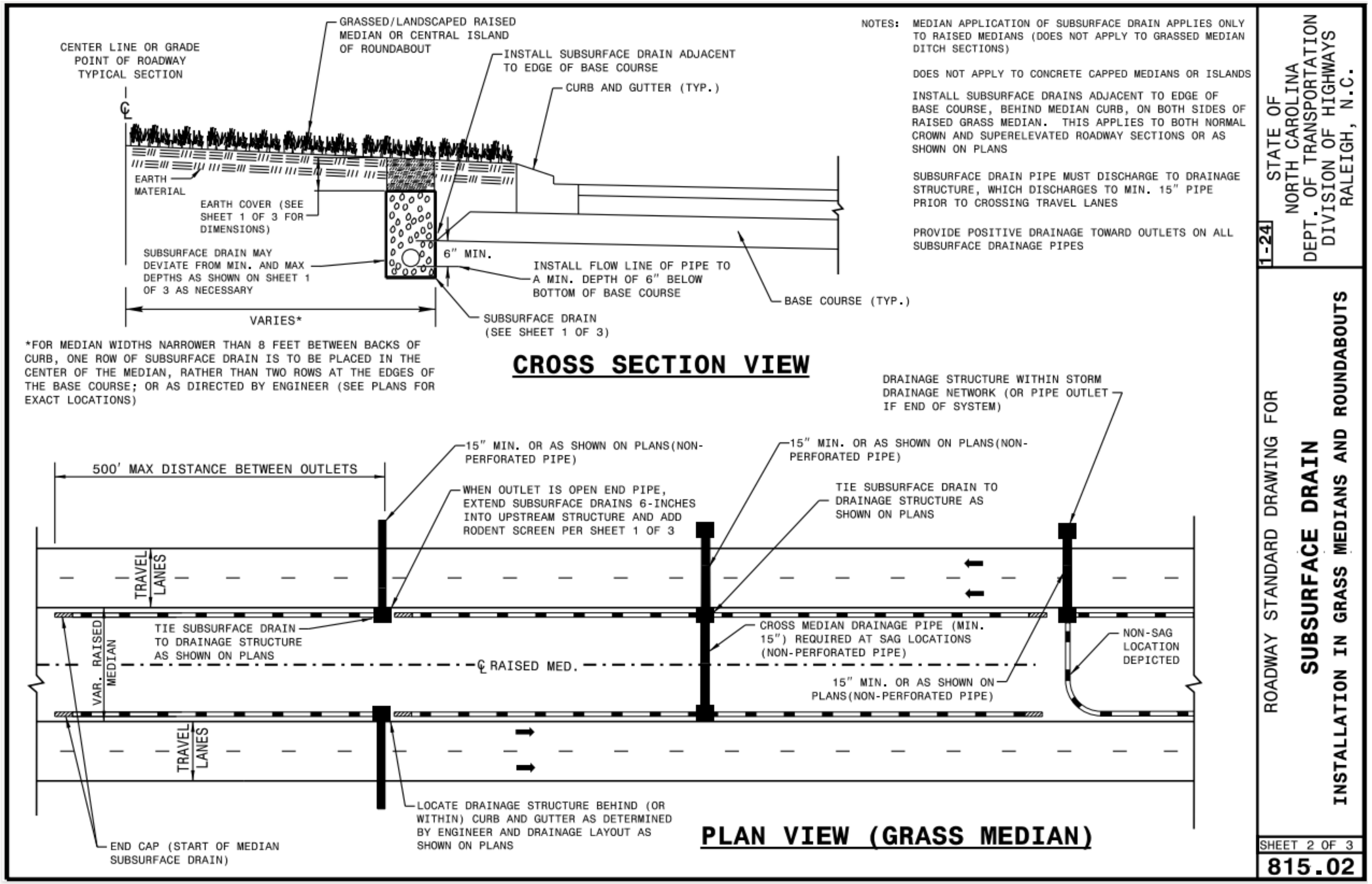
ROADWAY STANDARD DRAWING FOR
CONCRETE OPEN THROAT CATCH BASIN
(WITH MANHOLE)
12" THRU 48" PIPE

SHEET 1 OF 2

840.04

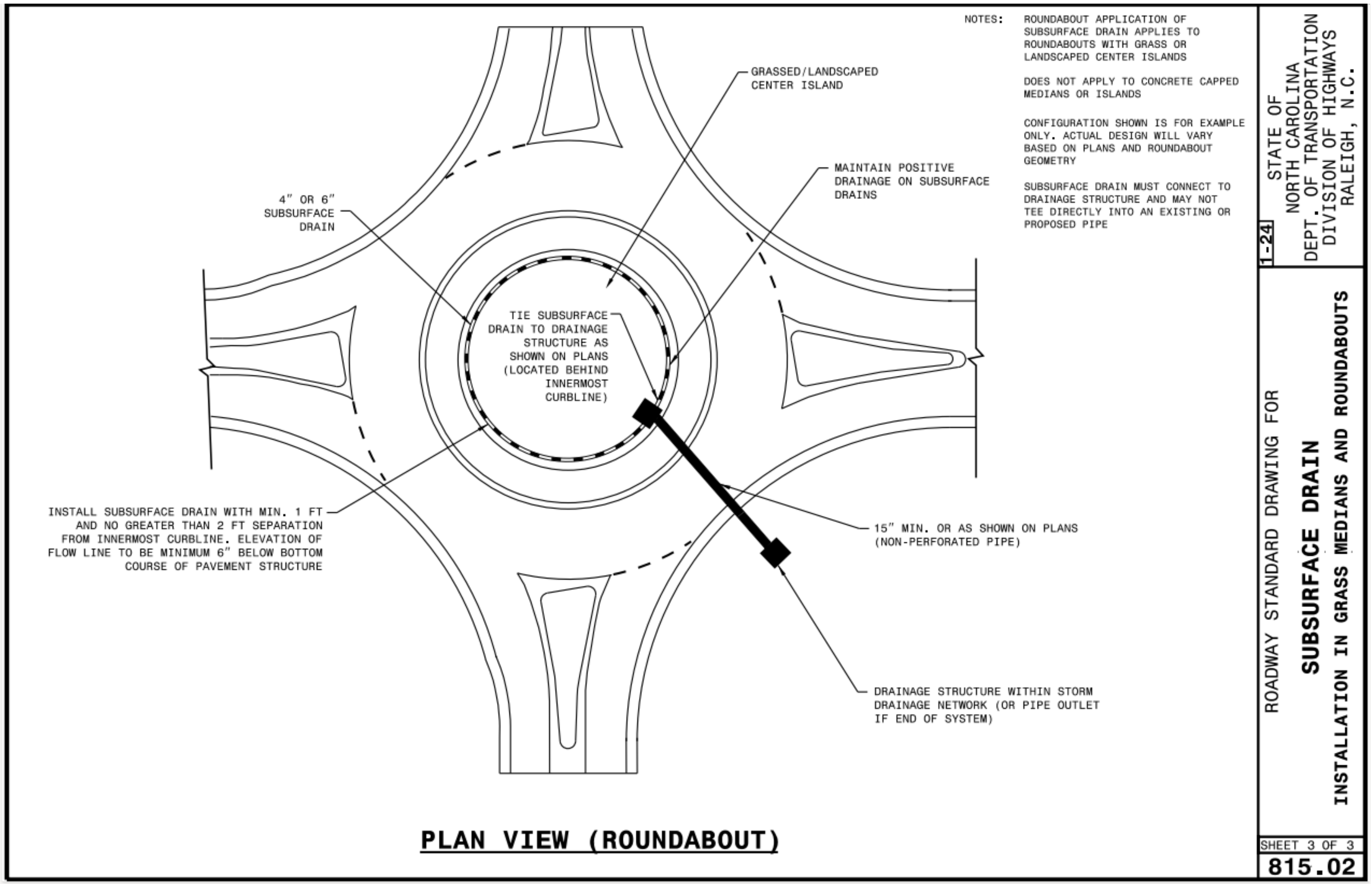
NCDOT Standard Drawings 2024 Changes

815.02 Subsurface Drains: To be placed in raised grass medians. Hydraulics Guidelines updates forthcoming.



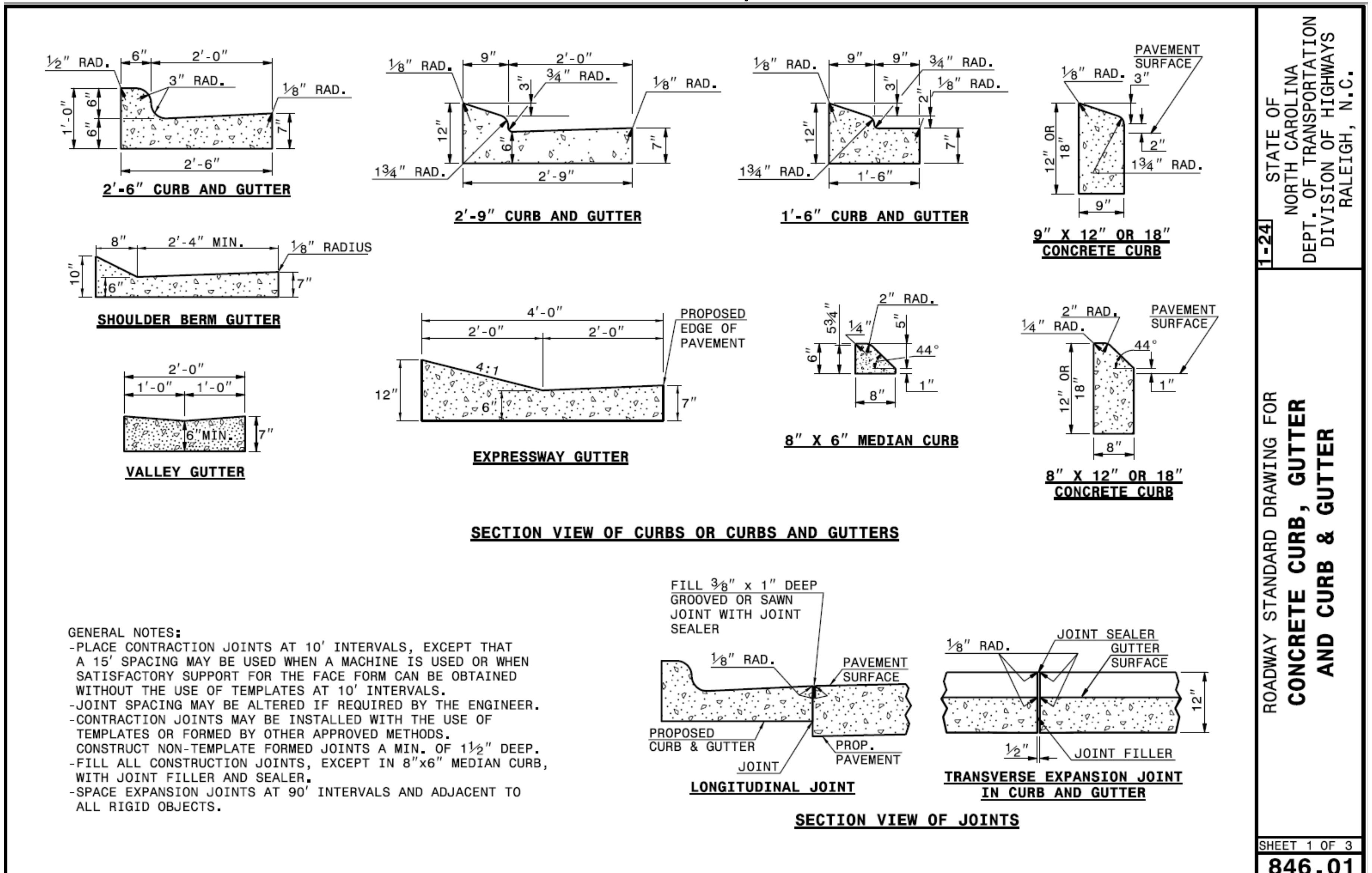
NCDOT Standard Drawings 2024 Changes

815.02 Subsurface Drains: To be placed in Roundabouts. Hydraulics Guidelines updates forthcoming.



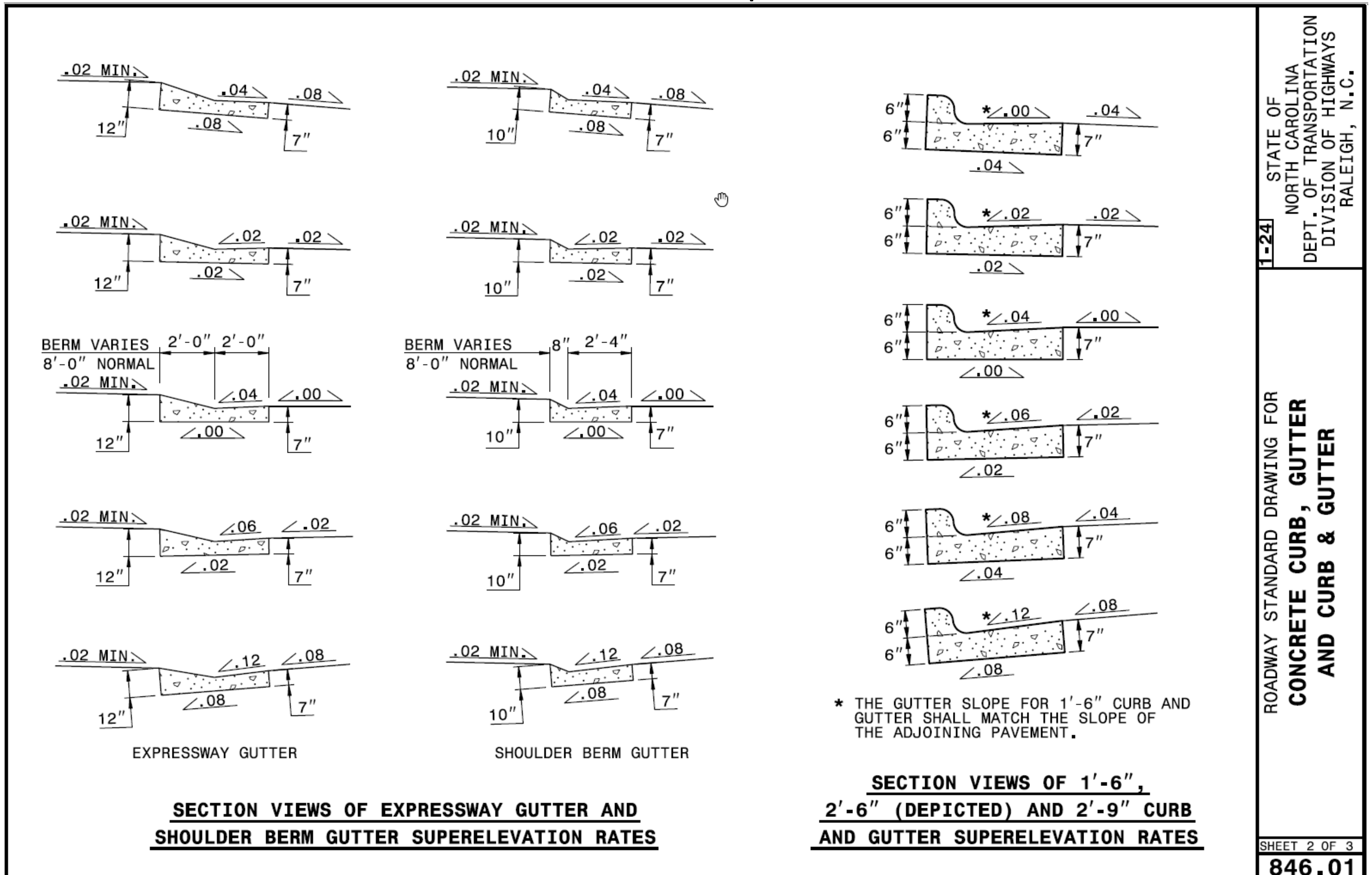
NCDOT Standard Drawings 2024 Changes

846.01 Curbs: 2’9” C&G added. Rollovers and Gutter Slopes Clarified

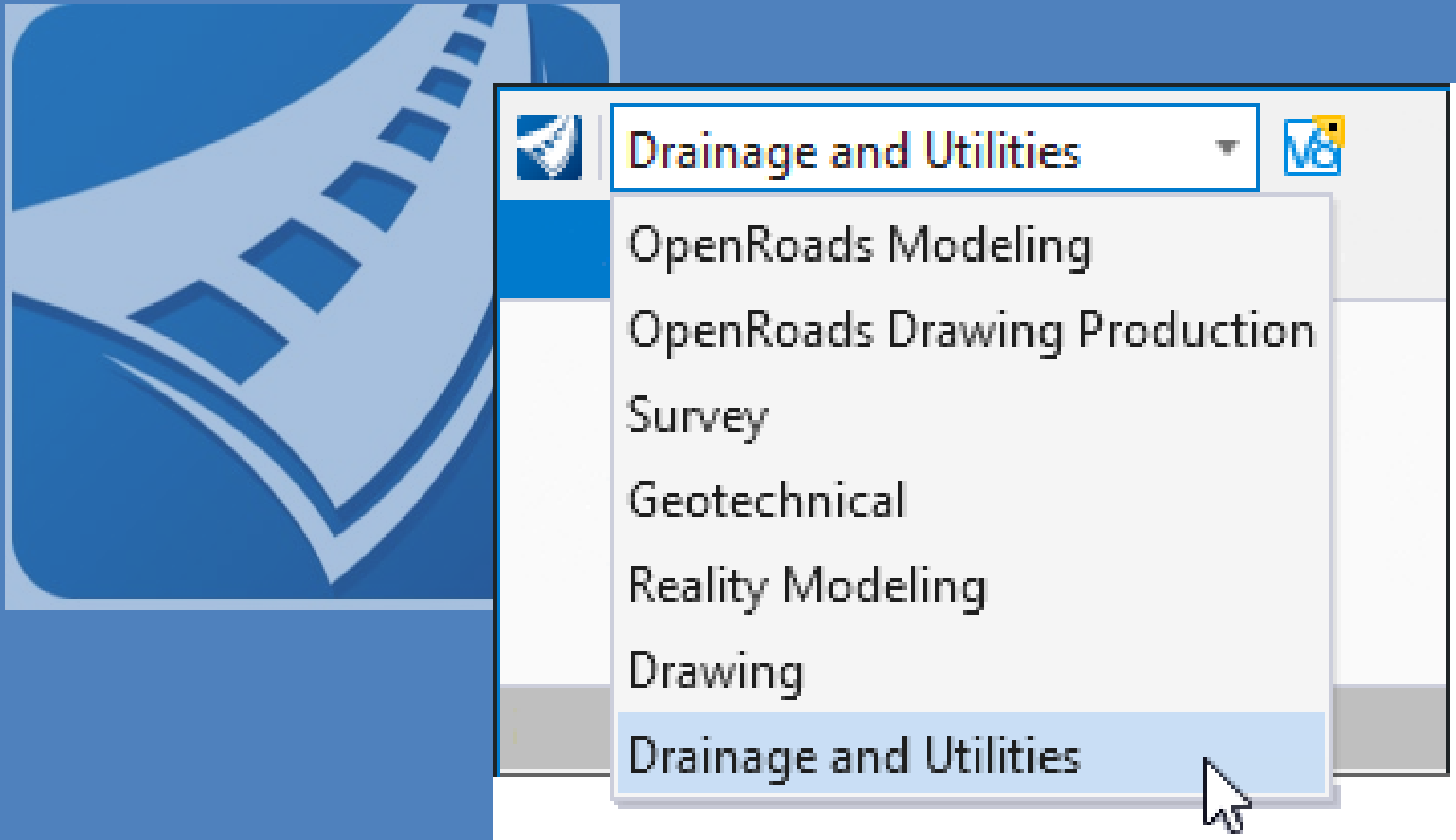


NCDOT Standard Drawings 2024 Changes

846.01 Curbs: 2’9” C&G added. Rollovers and Gutter Slopes Clarified



OpenRoads Designer®


Drainage and Utilities
OpenRoads Modeling
OpenRoads Drawing Production
Survey
Geotechnical
Reality Modeling
Drawing
Drainage and Utilities

ncdot.gov

Resources for ORD Drainage

OpenRoads Designer Applications

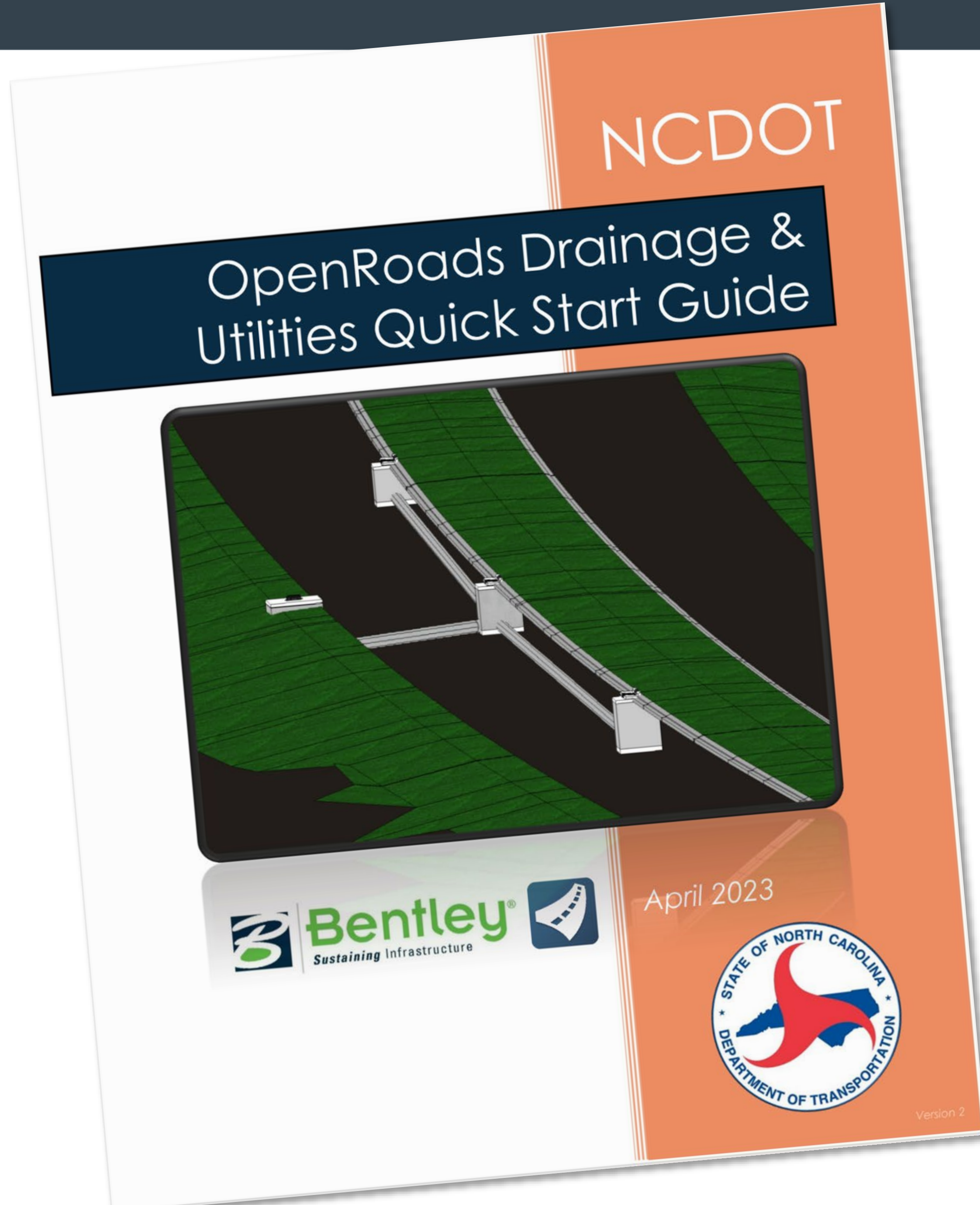
ORD version 10.09 or higher must be used.

- NCDOT ORD Drainage Manual (PDF)
- NCDOT ORD Ditch Design Manual (PDF)
- Updating Local ORD WorkSpaces (PDF)
- Inlet and Storm Drain with Instructions

Training

Bentley's OpenRoads Designer Drainage & Utilities Learning Path

2022 Summer NCLUG Ditch and Drainage Exercises



ORD Drainage Manual

ORD Drainage Manual

Resources for ORD Drainage

OpenRoads Designer Applications

ORD version 10.09 or higher must be used.

[illegible] ORD Di[illegible]ual PDF

NCDOT ORD Ditch Design Manual PDF

Updating Local ORD [illegible] PDF

Inlet and Storm Drain with Instructions

Training

Bentley's OpenRoads Designer Drainage & Utilities Learning Path

2022 Summer NCLUG Ditch and Drainage Exercises

NCDOT Hydraulics Unit
Standard Workflows for Ditch Design Using OpenRoads Designer

ORD 2021 R1 (v. 10.10.01.03)

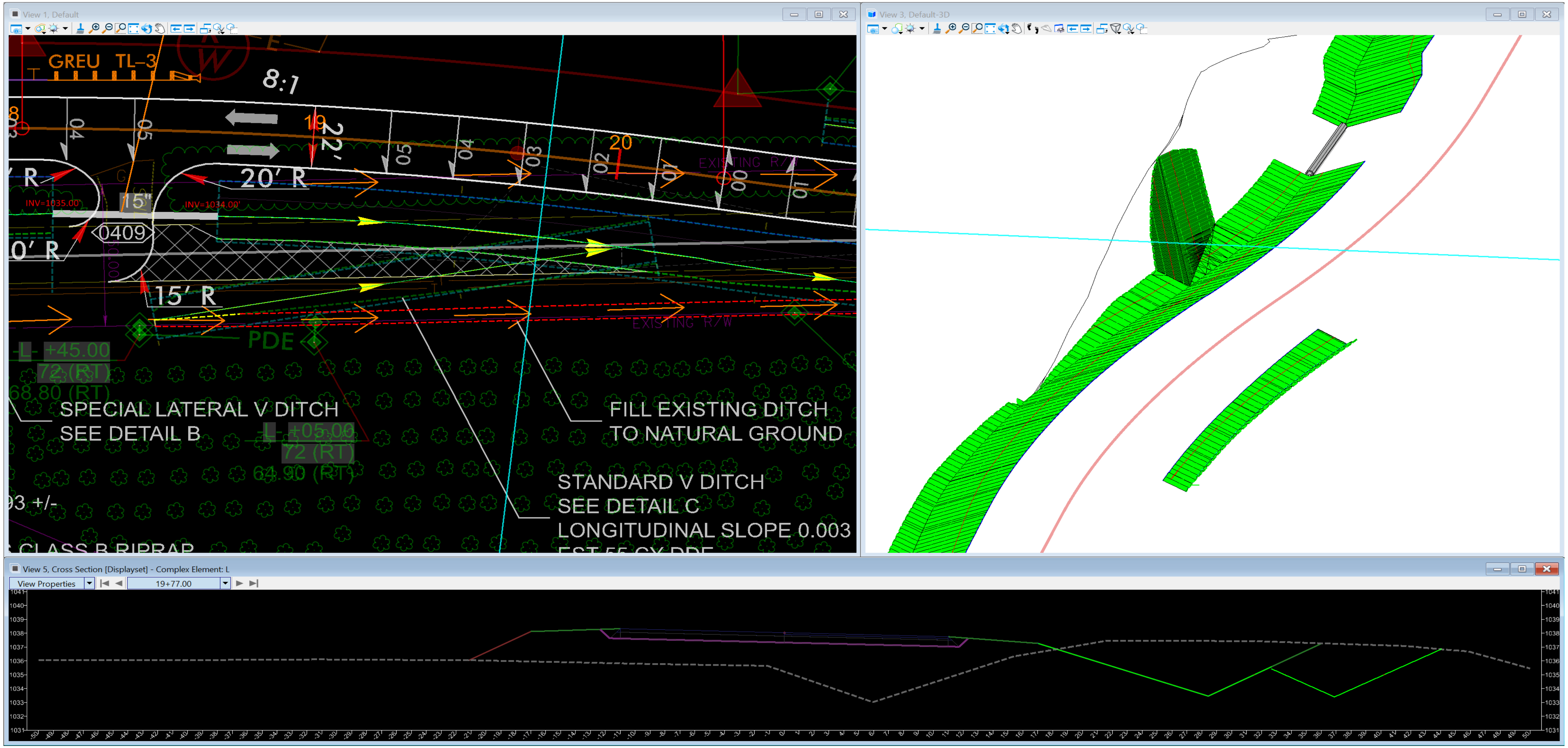
May 23, 2022

ORD Ditch Manual


NCDOT Hydraulics Unit
Standard Workflows for Ditch Design Using OpenRoads Designer

NEW VERSION COMING SOON

ORD Ditch Manual



ORD Ditch Manual

ncdot.gov

Connect NCDOT
BUSINESS PARTNER RESOURCES

Home Help Site Map

Doing Business | Bidding & Letting | Projects | Resources | Local Governments

Search...

Asset Management | Environmental | Geotechnical | GIS | Hydraulics | Materials & Tests | Photogrammetry | Contract Standards | Mapping Resources

Resources for ORD Drainage

Connect NCDOT ▶ Resources ▶ Hydraulics ▶ Resources for ORD Drainage

OpenRoads Designer Applications

ORD version 10.09 or higher must be used.

NCDOT ORD Drainage Manual PDF

NCDOT ORD Ditch Design Manual PDF

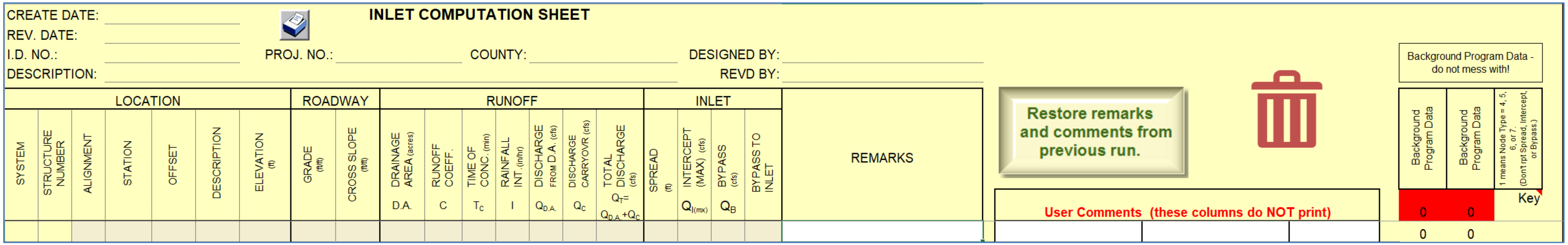
Updating Local ORD PDF

Inlet and Storm Drain with Instructions

Training

Bentley's OpenRoads Designer Drainage & Utilities Learning Path

2022 Summer NCLUG Ditch and Drainage Exercises



INLET COMPUTATION SHEET

CREATE DATE:
REV. DATE:
I.D. NO.: PROJ. NO.: COUNTY: DESIGNED BY:
DESCRIPTION: REVD BY:

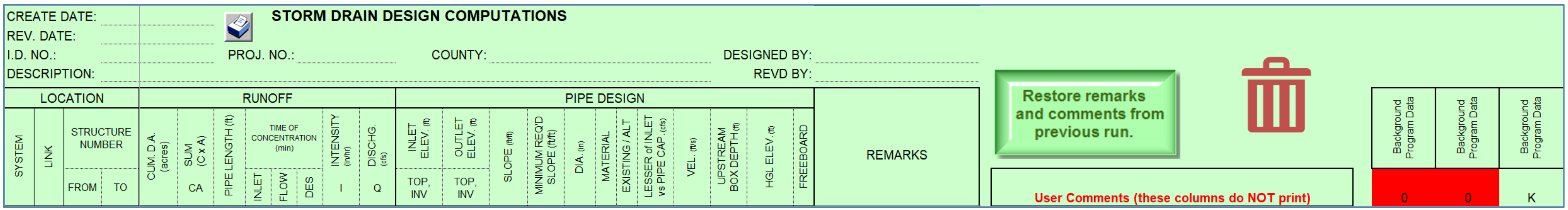
LOCATION							ROADWAY		RUNOFF							INLET				REMARKS
SYSTEM	STRUCTURE NUMBER	ALIGNMENT	STATION	OFFSET	DESCRIPTION	ELEVATION (ft)	GRADE (ft/ft)	CROSS SLOPE (ft/ft)	DRAINAGE AREA (acres) D.A.	RUNOFF COEFF. C	TIME OF CONC. (min) T_c	RAINFALL INT. (in/hr) I	DISCHARGE FROM D.A. (cfs) $Q_{D.A.}$	DISCHARGE CARRYOVR (cfs) Q_C	TOTAL DISCHARGE (cfs) $Q_T = Q_{D.A.} + Q_C$	SPREAD (ft)	INTERCEPT (MAX) (cfs) $Q_{I(max)}$	BYPASS (cfs) Q_B	BYPASS TO INLET	

Restore remarks and comments from previous run.

User Comments (these columns do NOT print)

Background Program Data - do not mess with!

Background Program Data	Background Program Data	1 means Node Type = 4, 5, 6, or 7. (Dont rpt Spread, Intercept, or Bypass.)
0	0	Key
0	0	



STORM DRAIN DESIGN COMPUTATIONS

CREATE DATE:
REV. DATE:
I.D. NO.: PROJ. NO.: COUNTY: DESIGNED BY:
DESCRIPTION: REVD BY:

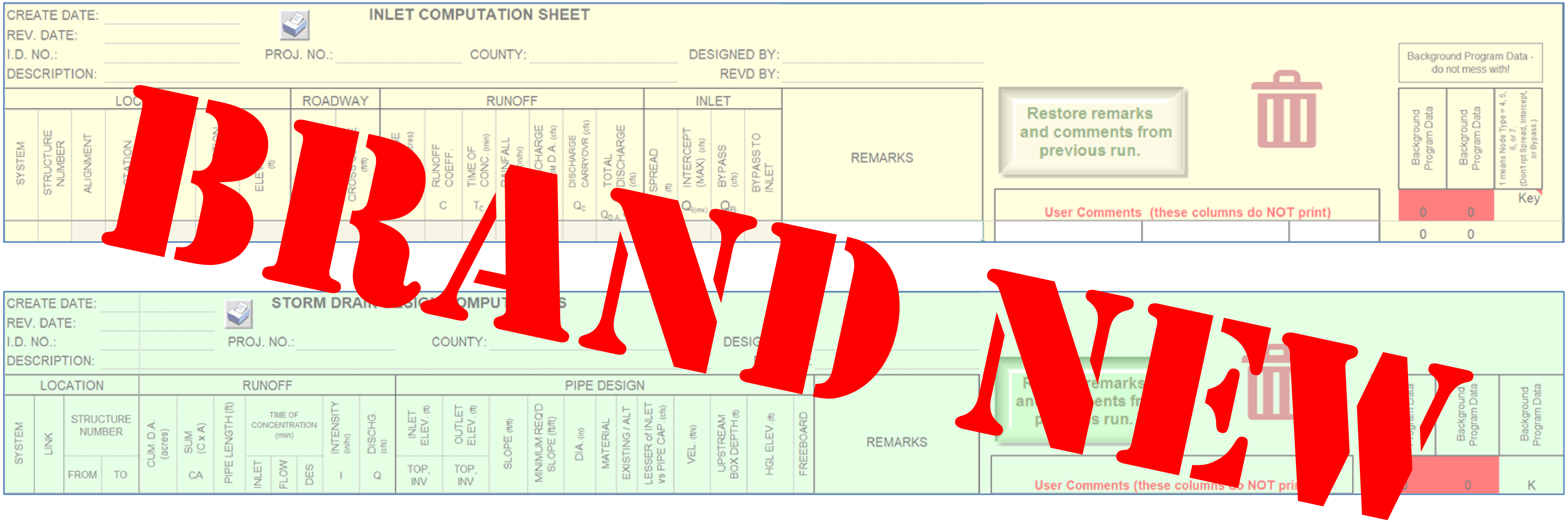
LOCATION				RUNOFF								PIPE DESIGN												REMARKS
SYSTEM	LINK	STRUCTURE NUMBER FROM	STRUCTURE NUMBER TO	CUM. D.A. (acres)	SUM (C x A) CA	PIPE LENGTH (ft)	TIME OF CONCENTRATION (min) INLET	TIME OF CONCENTRATION (min) FLOW	TIME OF CONCENTRATION (min) DES	INTENSITY (in/hr) I	DISCHG. (cfs) Q	INLET ELEV. (ft) TOP, INV	OUTLET ELEV. (ft) TOP, INV	SLOPE (ft/ft)	MINIMUM REQ'D SLOPE (ft/ft)	DIA. (in)	MATERIAL	EXISTING / ALT	LESSER of INLET vs PIPE CAP. (cfs)	VEL. (ft/s)	UPSTREAM BOX DEPTH (ft)	HGL ELEV. (ft)	FREEBOARD	

Restore remarks and comments from previous run.

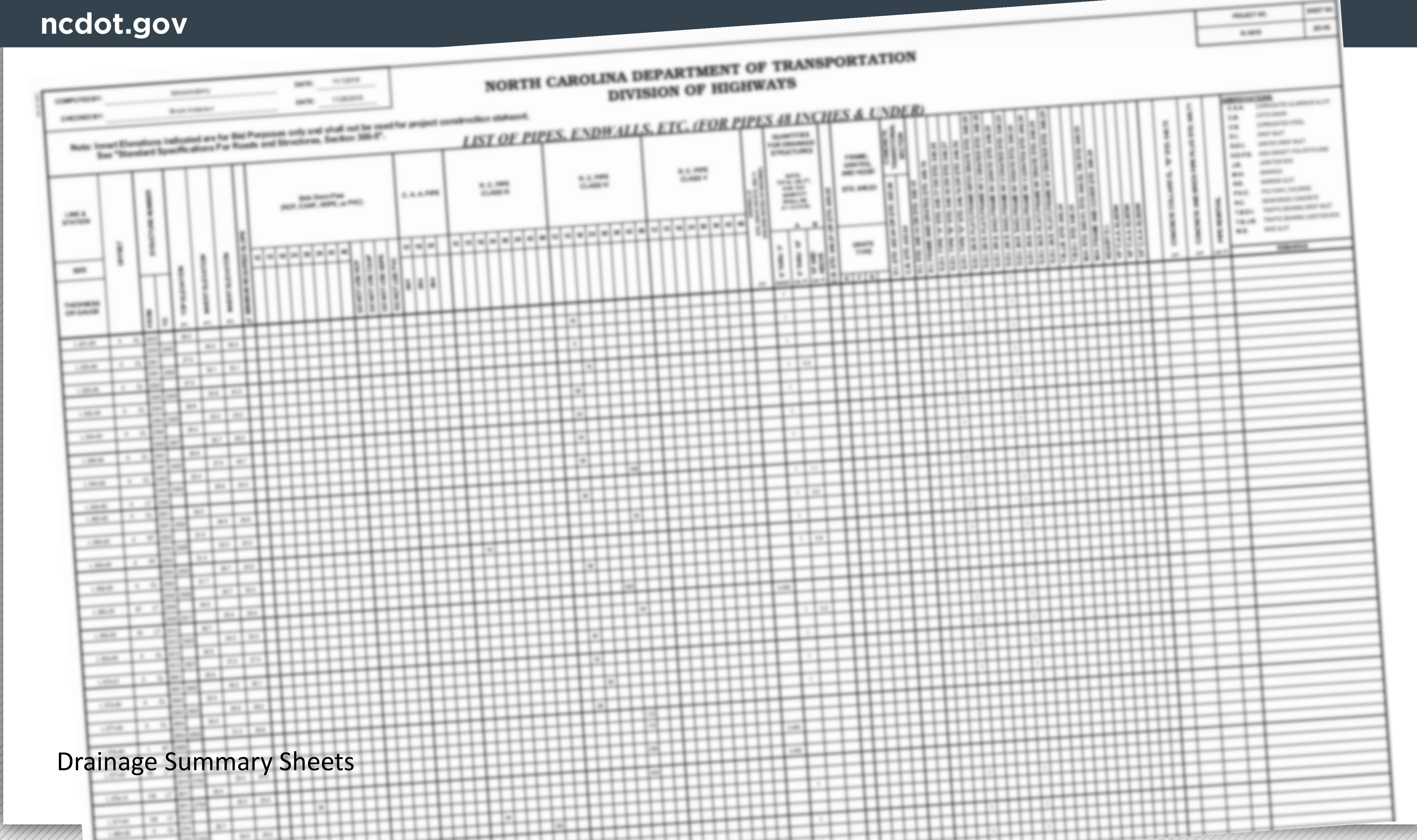
User Comments (these columns do NOT print)

Background Program Data	Background Program Data	Background Program Data
0	0	K

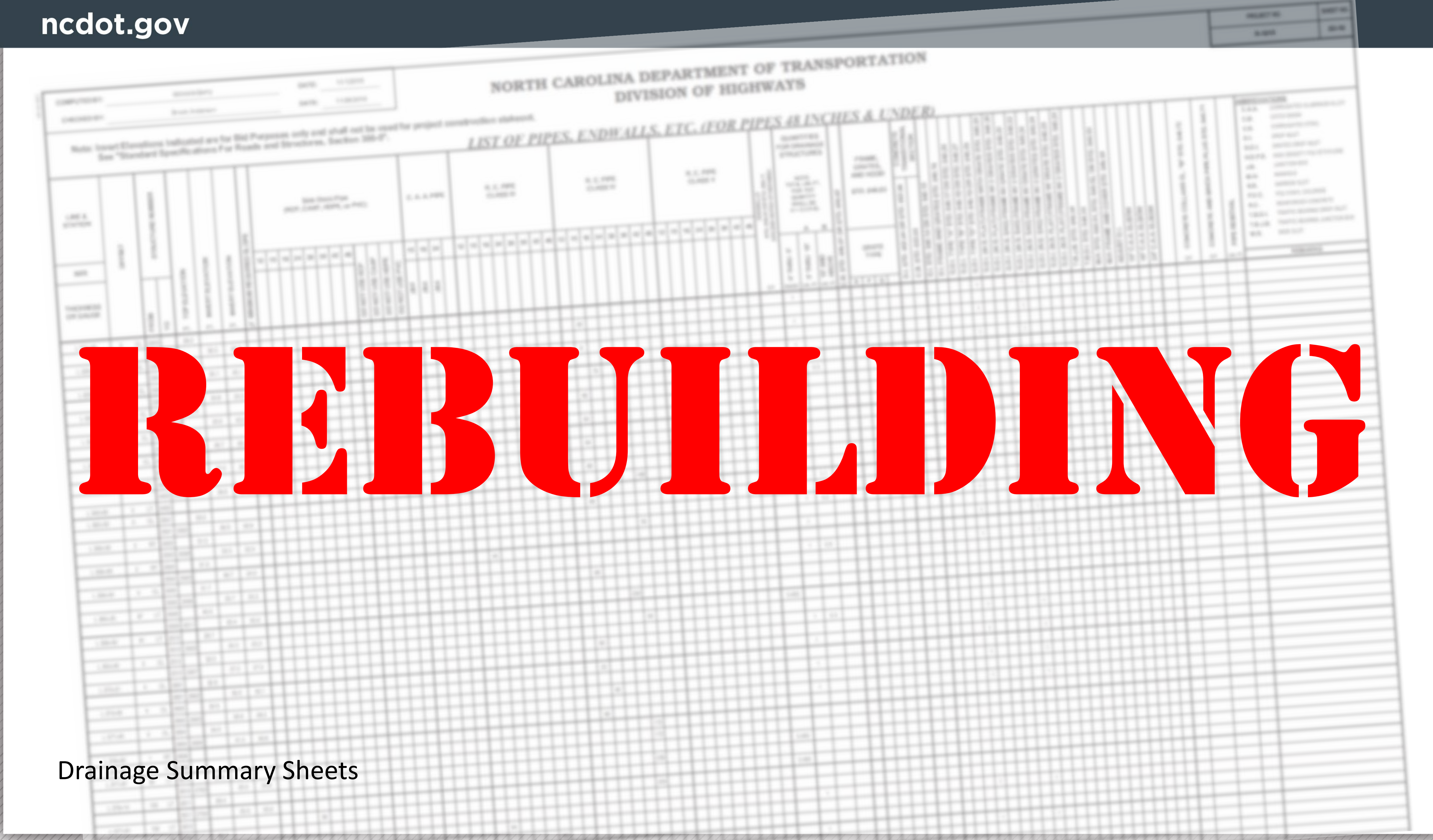
Inlet and Storm Drain Design Computation Sheets



Inlet and Storm Drain Design Computation Sheets

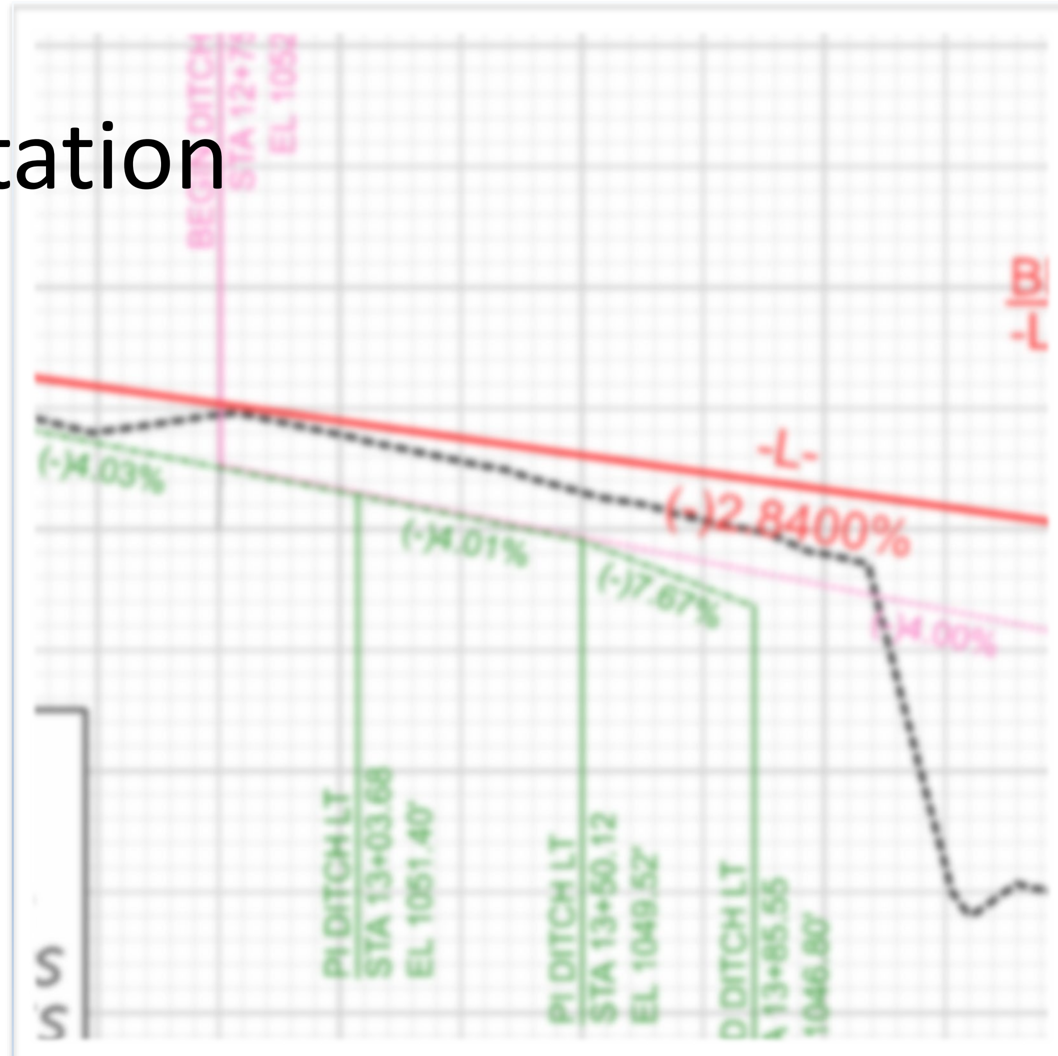


Drainage Summary Sheets

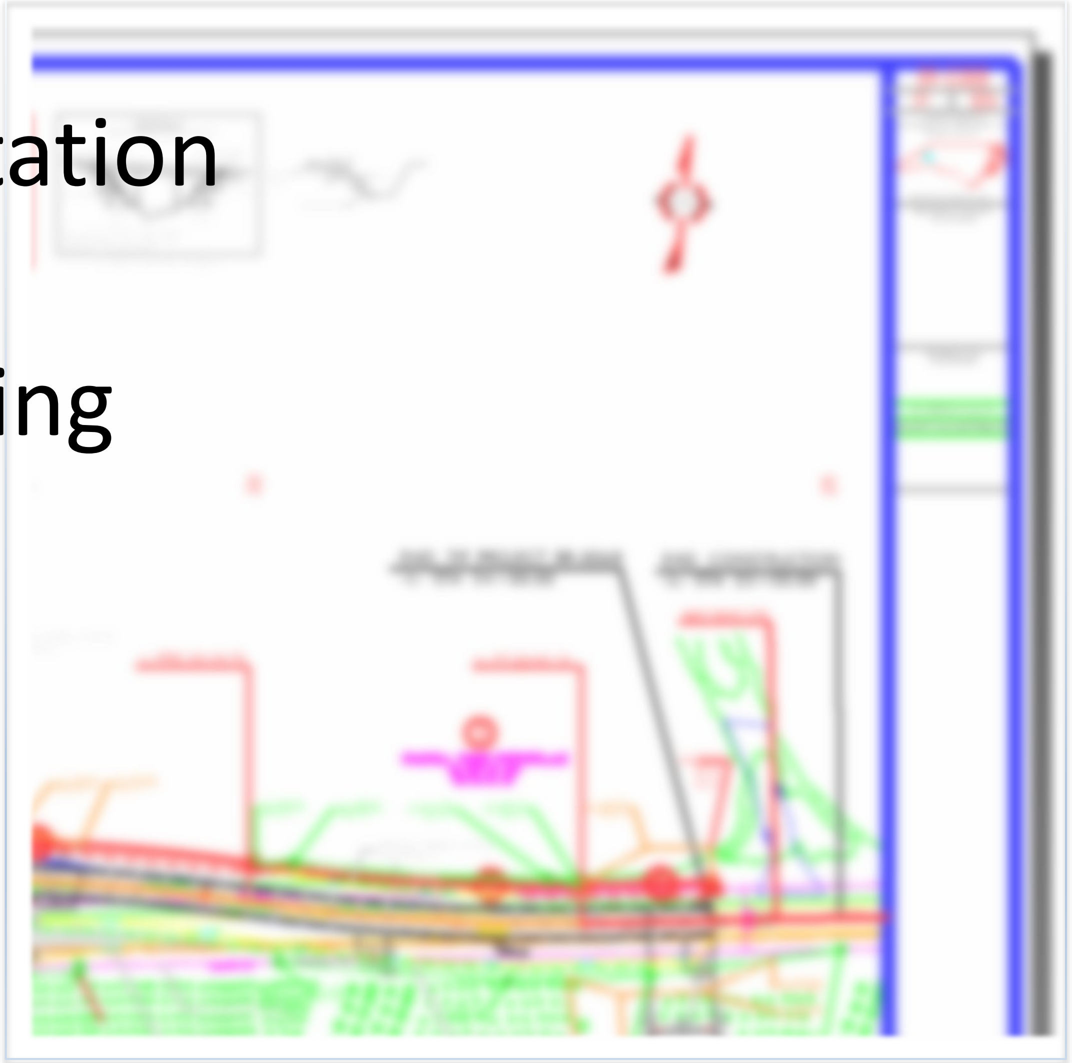


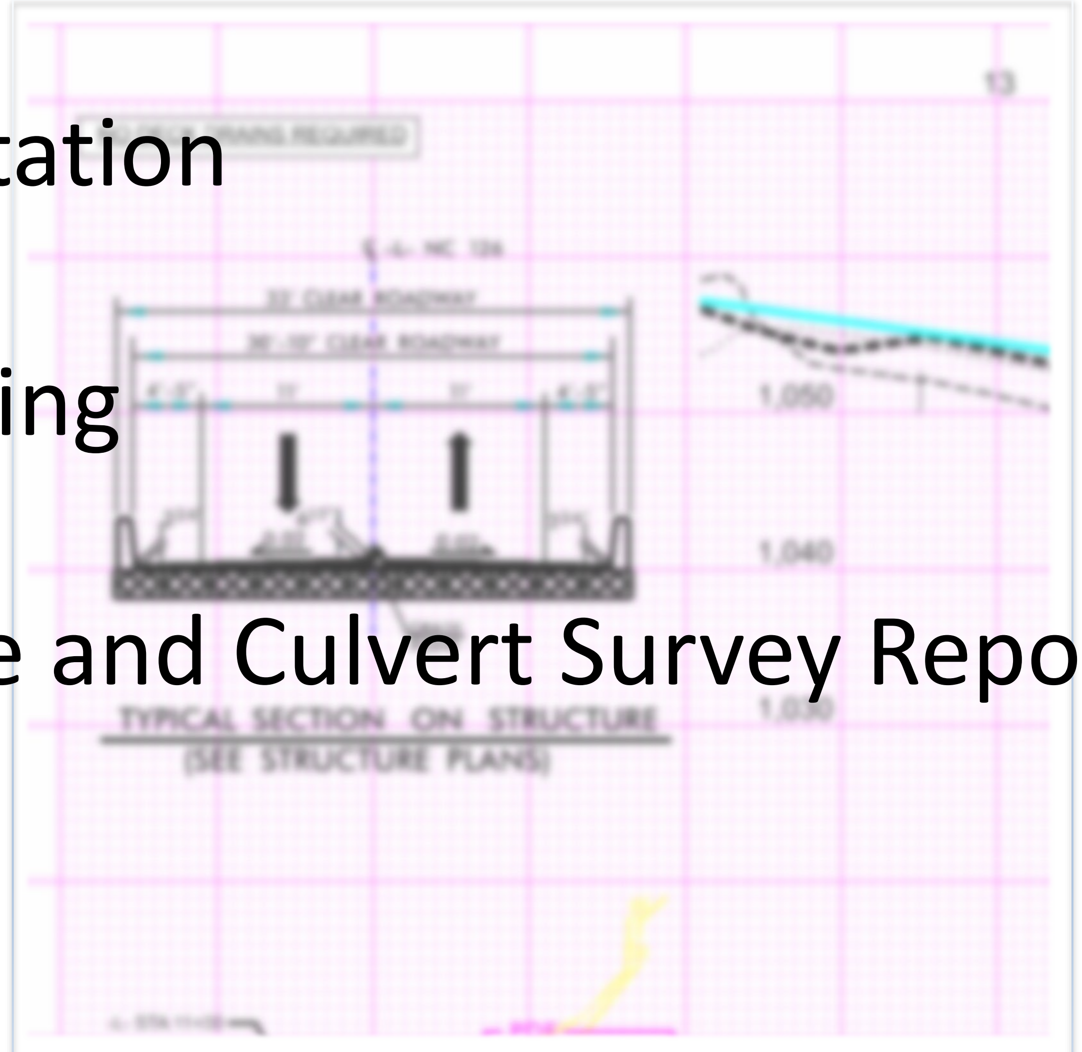
Drainage Summary Sheets

- Annotation


-L-
(-)2.8400%
(-)4.03%
(-)4.01%
(-)7.67%
PI DITCH LT
STA 13+03.68
EL 1051.40'
PI DITCH LT
STA 13+50.12
EL 1049.52'

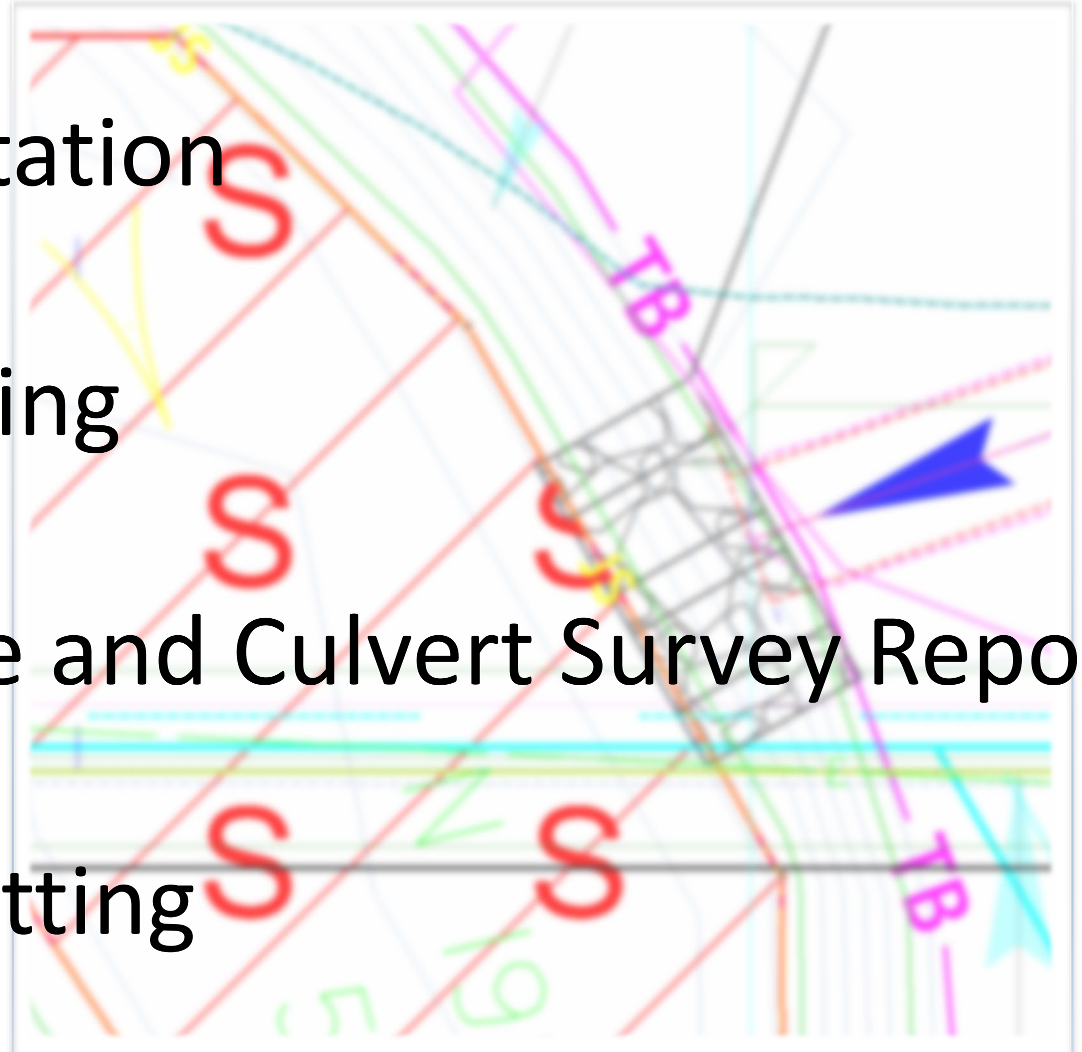
- Annotation
- Sheeting





- Annotation
- Sheeting
- Bridge and Culvert Survey Reports

- Annotation
- Sheeting
- Bridge and Culvert Survey Reports
- Permitting



- Annotation
- Sheeting
- Bridge and Culvert Survey Reports
- Permitting

IN THE WORKS

Resources for ORD Drainage

OpenRoads Designer Applications

ORD version 10.09 or higher must be used.

- NCDOT ORD Drainage Manual (PDF)
- NCDOT ORD Ditch Design Manual (PDF)
- Updating Local ORD WorkSpaces (PDF)
- Inlet and Storm Drain with Instructions

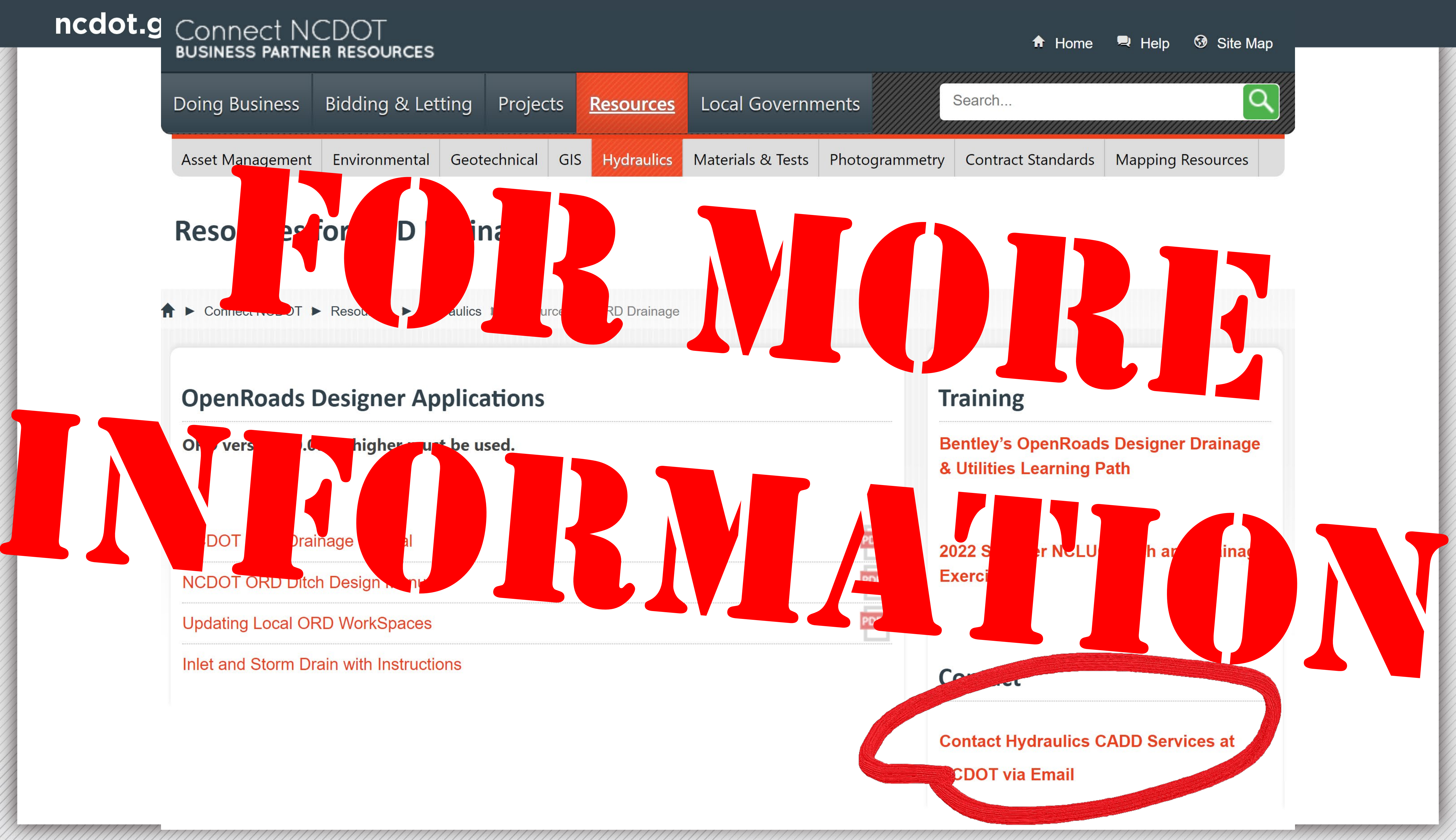
Training

Bentley's OpenRoads Designer Drainage & Utilities Learning Path

2022 Summer NCLUG Ditch and Drainage Exercises

Contact

Contact Hydraulics CADD Services at NCDOT via Email


ncdot.g
Connect NCDOT
BUSINESS PARTNER RESOURCES
Home
Help
Site Map
Doing Business
Bidding & Letting
Projects
Resources
Local Governments
Search...
Asset Management
Environmental
Geotechnical
GIS
Hydraulics
Materials & Tests
Photogrammetry
Contract Standards
Mapping Resources
FOR MORE INFORMATION
OpenRoads Designer Applications
NCDOT ORD Ditch Design
Updating Local ORD WorkSpaces
Inlet and Storm Drain with Instructions
Training
Bentley's OpenRoads Designer Drainage & Utilities Learning Path
Contact Hydraulics CADD Services at
CDOT via Email

North Carolina Department of Transportation

Hydraulics Unit

Mailing Address
1590 Mail Service Center
Raleigh, NC 27699-1590

Physical Address
1000 Birch Ridge Drive
Raleigh, NC 27610

E-mail:
hydraulicCADDsupport@ncdot.gov

Additional Drainage and Utilities Resources

Hydraulics Resources for ORD
(NCDOT Connect website)
connect.ncdot.gov/resources/hydro/Pages/ORD-Drainage-Resources.aspx

OpenRoads Drainage and Utilities Quick Start Guide
connect.ncdot.gov/resources/hydro/ORDFiles/Drainage%20Manual%20Third%20Draft.pdf

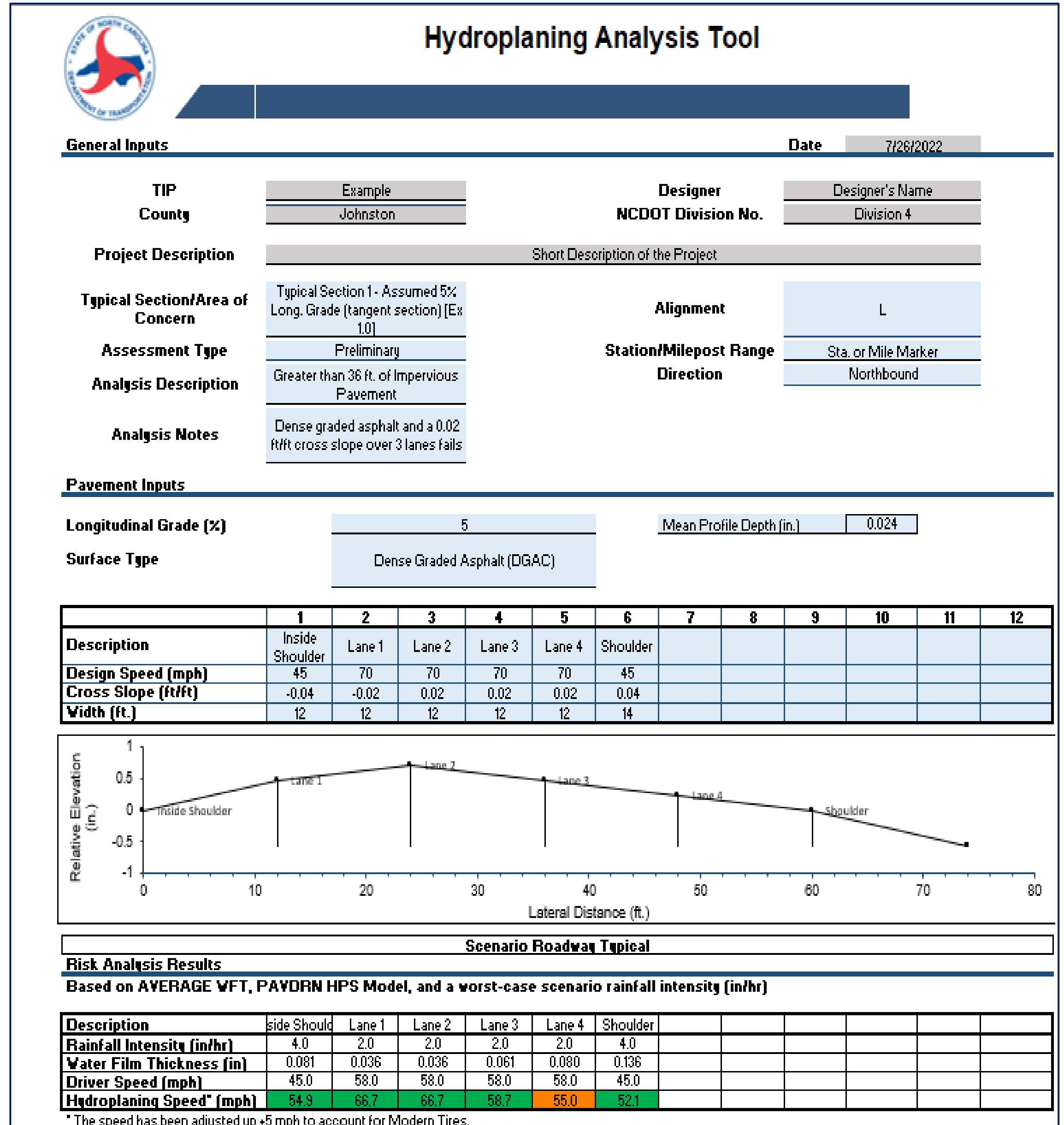
Hydroplaning Analysis Guidance Updates

- **Hydroplaning Concerns Identified Early**
  - ➢ PDN Stage 2HY1, Preliminary Roadway Typical Section Review
- **Hydroplaning Assessment for Roadway Typical Sections and Areas of Concern**
  - ➢ PDN Stage 2HY2, Hydraulics Planning Report - Review of Roadway Design Plans for Drainage Issues
- **New North Carolina-specific MPD Values**
- **Hydroplaning Speed Adjustment for Modern Tire Inflation and Tread Patterns**
- **Mitigation Strategies**

ncdot.gov

Hydroplaning Assessment Tool

https://connect.ncdot.gov/resources/hydro/DrainageStudiesGuidelines/NCDOTHydroplaningAssessmentTool.xlsm



Hydroplaning Analysis Tool

General Inputs — Date: 7/26/2022

TIP	Example	Designer	Designer's Name
County	Johnston	NCDOT Division No.	Division 4
Project Description	Short Description of the Project		
Typical Section/Area of Concern	Typical Section 1 - Assumed 5% Long. Grade (tangent section) [Ex 1.0]	Alignment	L
Assessment Type	Preliminary	Station/Milepost Range	Sta. or Mile Marker
Analysis Description	Greater than 36 ft. of Impervious Pavement	Direction	Northbound
Analysis Notes	Dense graded asphalt and a 0.02 ft/ft cross slope over 3 lanes fails		

Pavement Inputs

Longitudinal Grade (%)	5	Mean Profile Depth (in.)	0.024
Surface Type	Dense Graded Asphalt (DGAC)		

	1	2	3	4	5	6	7	8	9	10	11	12
Description	Inside Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Design Speed (mph)	45	70	70	70	70	45						
Cross Slope (ft/ft)	-0.04	-0.02	0.02	0.02	0.02	0.04						
Width (ft.)	12	12	12	12	12	14						

Scenario Roadway Typical

Risk Analysis Results

Based on AVERAGE WFT, PAVDRN HPS Model, and a worst-case scenario rainfall intensity (in/hr)

Description	side Should	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Rainfall Intensity (in/hr)	4.0	2.0	2.0	2.0	2.0	4.0						
Water Film Thickness (in)	0.081	0.036	0.036	0.061	0.080	0.136						
Driver Speed (mph)	45.0	58.0	58.0	58.0	58.0	45.0						
Hydroplaning Speed* (mph)	54.9	66.7	66.7	58.7	55.0	52.1						

* The speed has been adjusted up +5 mph to account for Modern Tires.

Future Hydroplaning Improvements

- **Pre-approved Roadway Typical Sections**
  - *No further hydroplaning analysis required for select sections*
  - *Superelevation transitions still evaluated*
- **Research – Driver Speed Reductions During Rain Events**
  - *Using Bridge Watch rainfall data and HERE speed data.*
- **Mitigation Selection Guide**
  - *Assist designers in selecting the most appropriate and cost-prudent mitigation strategy*

More Future Hydroplaning Improvements

- **NCDOT Hydroplaning Assessment Tool**
  - *User friendly and production oriented*
- **Continued Work to Address Superelevation Transitions**
  - *Coordination with FHWA's Argonne Laboratory*
  - *Examine both WFTs and mitigation strategies*

Hydroplaning Mitigation Selection Guide

Select mitigation topic for more information -->	PAVEMENT MITIGATION						GEOMETRIC CHANGES							SIGNAGE		
	Pavement Overlays			Surface Treatments			Modifying Roadway Typical		Intercepting Pavement Runoff		Managing Roadway Geometry			Signage Strategies		
	Open Graded Friction Course[1]	Ultra Thin Bonded Wearing Course	High Surface Friction Treatment[3]	Diamond Grooving[4]	Diamond Grinding	Shotblasting	Slope Shoulder Away	Moving the Crown Point	Gore Valley Gutters	Slotted or Trench Drain	Flatten Longitudinal Slope	Increase Cross Slopes	Adjust SE Transitions	Static Signs	Static Signs with Emphasis	Dynamic Signs
Applicable Project Type (New Pavement[2], Widening, Maintenance)	All	All	Widening or Maintenance	Widening or Maintenance	All	Maintenance	All	All	Widening or Maintenance	Widening or Maintenance	New Pavement	All	All	All	All	New Pavement or Widenings
Spatial Exent[5]	Global	Global	Local	Both	Both	Both	Global	Global	Local	Local	Global	Global	Both	Both	Both	Both
Construction Costs	$$	$$	$$$	$$$	$$$	$$	$	$	$	$$	$	$	$$	$	$	$$
Maintenance Effort	medium	medium	high	medium	medium	high	low	low	low	medium	low	low	low	low	low	medium
Service Life	8-10 years	9-11 years	8-12 years	15 years	15 years	2-5 years	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10 years	10 years	15-20 years
Suitable for the Following Existing Pavement Surfaces[6]	DGAC Concrete UTBWC	DGAC Concrete	DGAC Concrete	Concrete DGAC[4]	Concrete	DGAC Concrete OGFC	All Pavement Surfaces	All Pavement Surfaces	All Pavement Surfaces	All Pavement Surfaces	All Pavement Surfaces	All Pavement Surfaces	All Pavement Surfaces	Applicable for all pavement surfaces including temporary construction conditions.[7]		
Hydroplaning Benefit ★ to ★★★	★★★	★★½	★★★	★★★ (transverse grooving)	★½	★★	★	★★½	★★★	★★★	★	★½	★★★	Effectiveness is unknown at this time. Further research is needed.		

Notes:

General Note: Mitigation strategies can be combined for greater hydroplaning potential reduction. Example: geometry, pavement type, or surface treatment.

(1) Open Graded Friction Course is not recommended for regions prone to frequent ice/snow events or longitudinal slopes steeper than 5%. (Divisions 11, 13 and 14)

(2) New pavement consists of new and/or reconstructed pavement.

(3) High Friction Surface Treatment is only applicable for DGAC or Concrete pavement and treatment is vulnerable to maintenance issues in Divisions where sand is used in ice/snow conditions.

(4) Diamond grooving is typically reserved for bridge decks (see NCDOT Specification 420). DGAC grooving can be used for short segments, typically curves, as a spot treatment.

(5) Global treatments are applicable to the entire project limits; Local treatments are considered 'spot treatments' and used in smaller applications.

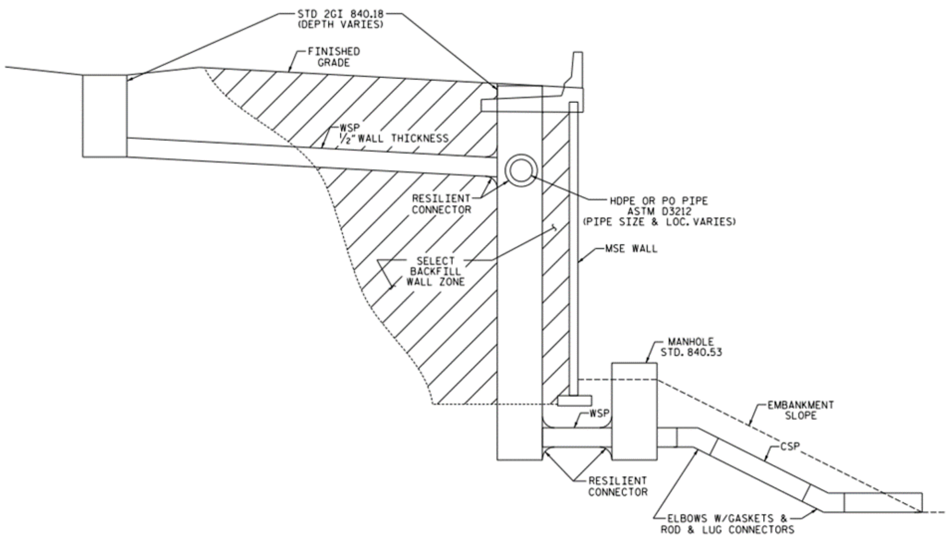
(6) If hydroplaning potential occurs in OGFC areas, consider geometric solutions.

(7) Variable message boards can be used during construction to warn of temporary hydroplaning concerns.

https://connect.ncdot.gov/resources/hydro/Pages/DrainageStudiesGuidelines.aspx

MSE Wall Drainage Guideline Development

TYPICAL STORM DRAINAGE PIPE LAYOUT AT MSE WALL ZONE
(NTS)



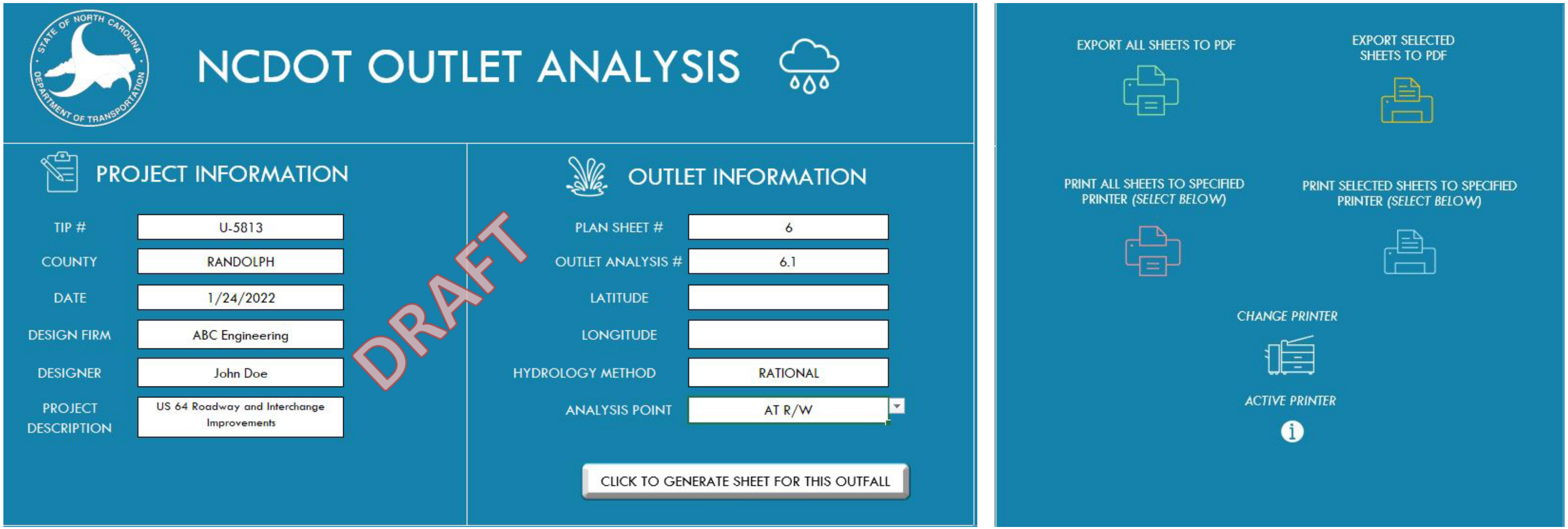
NCDOT DESIGN GUIDELINES FOR STORM DRAINAGE PIPES ADJACENT TO MSE WALLS

HYDRAULICS UNIT |

Outlet Analysis Tool

- **Creates a Consistent Way to Evaluate Pipe/Ditch Outlets**
  - ➢ PDN Stages 2HY2, Complete Drainage for Field Inspection
  - ➢ Utilizes Macros to Improve User Experience and Expedite Calculations
- **Spreadsheet Allows User to Enter General Project Information and Generate Specific Outlet Tabs**
  - **Choice of County**
    - ➢ Preloads County IDF tables to support Hydrology Calculations
  - **Choice of Hydrology Method**
    - ➢ Rational, TR-55, USGS – 5030, USGS – 5158, User Input
  - **Choice of Analysis Location**
    - ➢ Within R/W, At R/W, Outside of R/W
  - **Custom Printer Options**

Outlet Analysis Tool - Main Splash Page for user input



Outlet Analysis Tool

- **Unique Outlet Analysis Tabs incorporate the following:**
  - **Pre vs Post Construction Calculations**
    - ➢ Sub area inputs, TOC inputs, Geometry inputs
    - ➢ Utilizes Manning's Equation to Calculate Flows, Velocities, and Depth
    - ➢ Calculates Percent Change
  - **Choice of Soil Type**
    - ➢ Incorporates Soil Type and calculates permissible velocities according to 15A NCAC 04B .0109 rule guidance
  - **Allows Uploads of Photo Pages**
    - ➢ Up to 5 pages of photos with automated print areas
  - **User Input for Summary**
    - ➢ Allows for narrative to be written describing conditions unique to each outlet
  - **Conditional Color Formatting and Cell Protection**
    - ➢ Easily identify where inputs are needed and if calculations are up to date
    - ➢ Cell protection avoids accidental deletion or modification of calculated values

Individual Outlet Analysis Tab – Page #1

TIP Project:	U-5813	Date:	1/24/2022
County:	RANDOLPH	Design Firm:	ABC Engineering
Description:	US 64 Roadway and Interchange Improvem	Designer:	John Doe

PSH 6 OUTLET 6.1

ANALYSIS POINT TAKEN AT R/W

Latitude: 35.24343 Longitude: -78.34521 Google Maps

PRE-CONSTRUCTION — Rational Method

Click to Enter Pre-Sub Areas

		Q_2 =	5.27	cfs
		V_2 =	3.38	ft./s
$C_{composite}$ =	0.58	D_2 =	0.60	ft.
T.O.C (min.)	10.0	Q_5 =	6.13	cfs
I_2 (in/hr) =	4.58	V_5 =	3.54	ft./s
I_5 (in/hr) =	5.33	D_5 =	0.65	ft.
I_{10} (in/hr) =	5.82	Q_{10} =	6.69	cfs
I_{25} (in/hr) =	6.35	V_{10} =	3.63	ft./s
I_{50} (in/hr) =	6.70	D_{10} =	0.69	ft.
DA_{imp} (ac) =	1.00	Q_{25} =	7.3[illegible]	cfs
DA_{grass} (ac) =	0.50	V_{25} =	3.[illegible]	ft./s
DA_{total} (ac) =	2.00	D_{25} =	0.72	ft.
		Q_{50} =	7.71	cfs
% Imp. area =	50.0%	V_{50} =	3.78	ft./s
		D_{50} =	0.74	ft.

CALCULATE V_{PRE} & D_{PRE}

POST-CONSTRUCTION — Rational Method

Click to Enter Post-Sub Areas

		Q_2 =	6.22	cfs
		V_2 =	3.09	ft./s
$C_{composite}$ =	0.61	D_2 =	0.55	ft.
T.O.C (min.)	10.0	Q_5 =	7.23	cfs
I_2 (in/hr) =	4.58	V_5 =	3.22	ft./s
I_5 (in/hr) =	5.33	D_5 =	0.59	ft.
I_{10} (in/hr) =	5.82	Q_{10} =	7.90	cfs
I_{25} (in/hr) =	6.35	V_{10} =	3.29	ft./s
I_{50} (in/hr) =	6.70	D_{10} =	0.62	ft.
DA_{imp} (ac) =	1.23	Q_{25} =	8.62	cfs
DA_{grass} (ac) =	0.50	V_{25} =	3.37	ft./s
DA_{total} (ac) =	2.23	D_{25} =	0.65	ft.
		Q_{50} =	9.09	cfs
% Imp. area =	55.2%	V_{50} =	3.42	ft./s
		D_{50} =	0.67	ft.

CALCULATE V_{POST} & D_{POST}

PERCENT CHANGE (%)

DA_{total}=	11.5%
Q_2 =	18.0%
V_2 =	-8.8%
D_2 =	-8.0%
Q_5 =	18.0%
V_5 =	-9.1%
D_5 =	-9.0%
Q_{10} =	18.0%
V_{10} =	-9.2%
D_{10} =	-9.6%
Q_{25} =	18.0%
V_{25} =	-9.4%
D_{25} =	-10.2%
Q_{50} =	18.0%
V_{50} =	-9.5%
D_{50} =	-10.5%

Green = Calculated / good / up to date (color 210,255,210)
Red = Calculated, incorrect, or not up to date (color 255,165,165)
light blue = user iput (cells unlocked) (color 190,240,240)

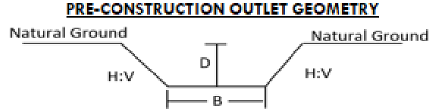
SOIL TYPE (Guidance Link): Sandy clay, silty clay, clay, weathered bedrock

$V_{10\ Permissible}$ 5.0 ft./s
$V_{10\ Post\text{-}Const}$ 3.3 ft./s

V10 < Vpermissible

PRE-CONSTRUCTION OUTLET GEOMETRY: Trapezoidal
POST-CONSTRUCTION OUTLET GEOMETRY: Trapezoidal

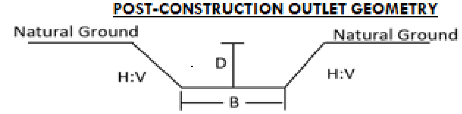
PRE-CONSTRUCTION OUTLET GEOMETRY



Depth (ft) =		H:V (Lt) =	1
Slope (ft/ft) =	0.0200	H:V (Rt) =	1
Manning's N =	0.0350	Base Width (ft.) =	2

Notes (lining, condition, etc.): Well vegetated grass/bush lined swale. No evidence of erosion issues shown.

POST-CONSTRUCTION OUTLET GEOMETRY



Depth (ft) =		H:V (Lt) =	3
Slope (ft/ft) =	0.0200	H:V (Rt) =	3
Manning's N =	0.0350	Base Width =	2

Notes (lining, condition, etc.): Add riprap for 20'.

Noteworthy Features:

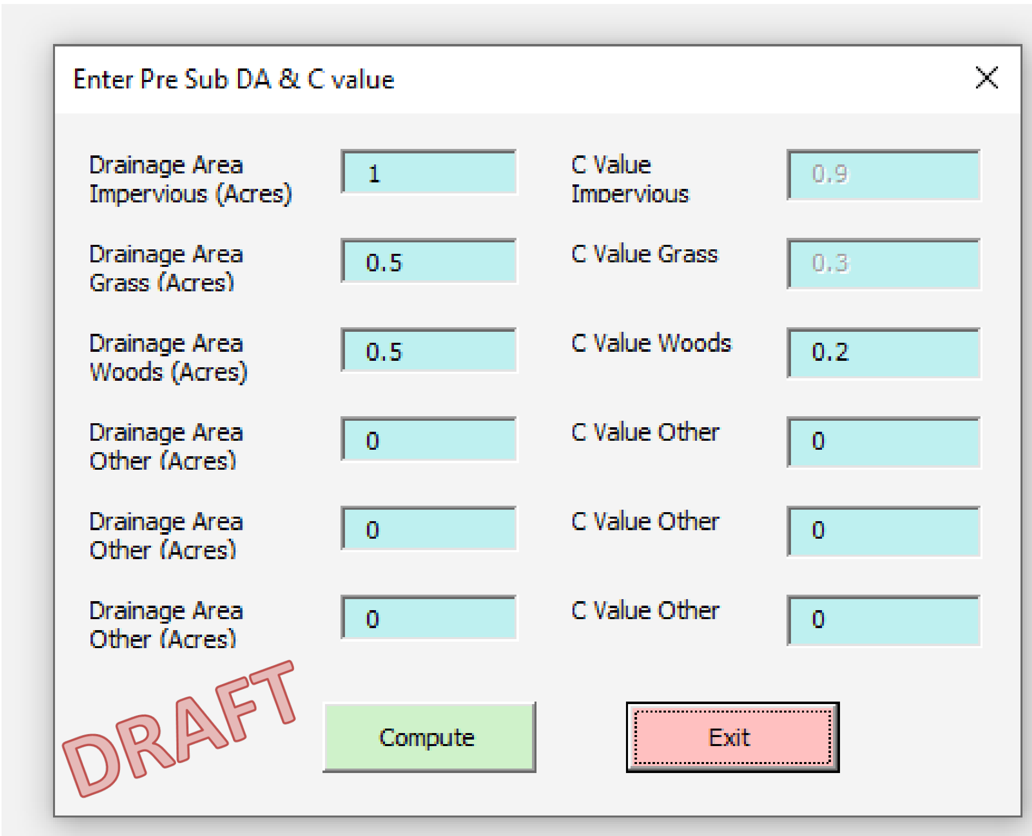
- Google Maps link
- Buttons to calculate Manning's equation
- V10 vs. Vpermissible validation
- User pop-up input forms
- Informational pop-up reference windows

Under Development:

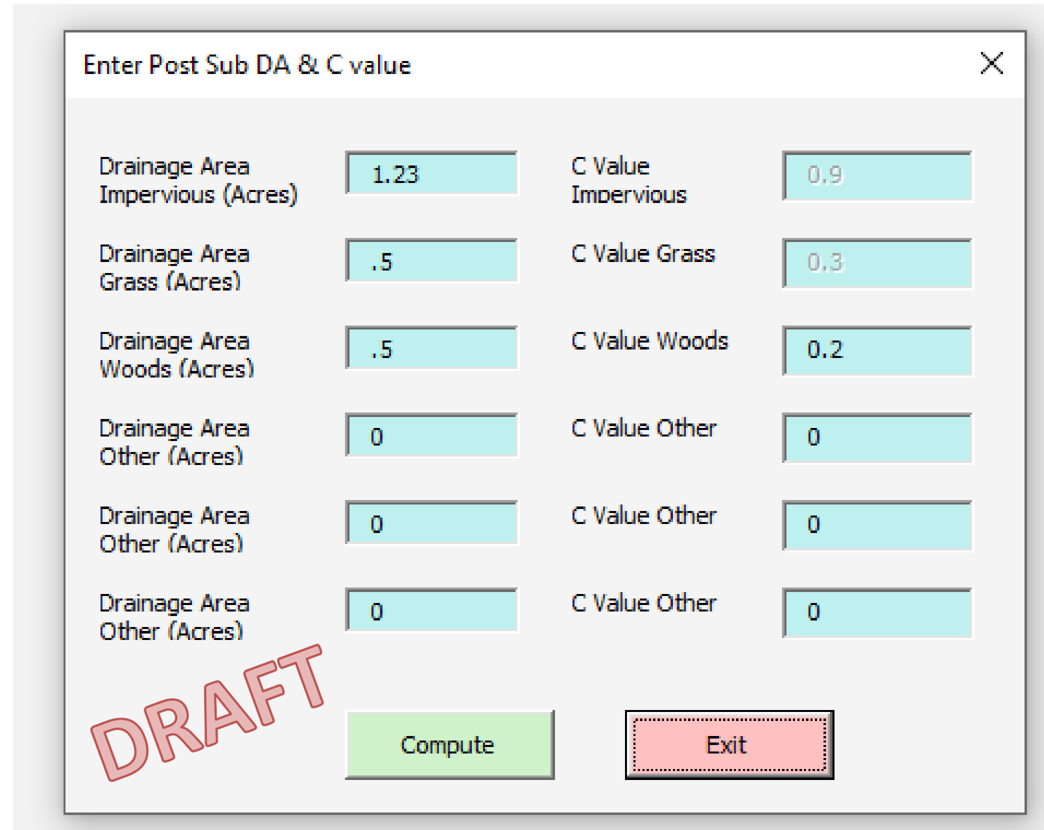
- Railroad right of way (100-yr) design toggle
- Functionality for project in multiple counties

Individual Outlet Analysis Tab – User Input Forms

Pre-Construction Drainage Area Inputs Po-Up Form



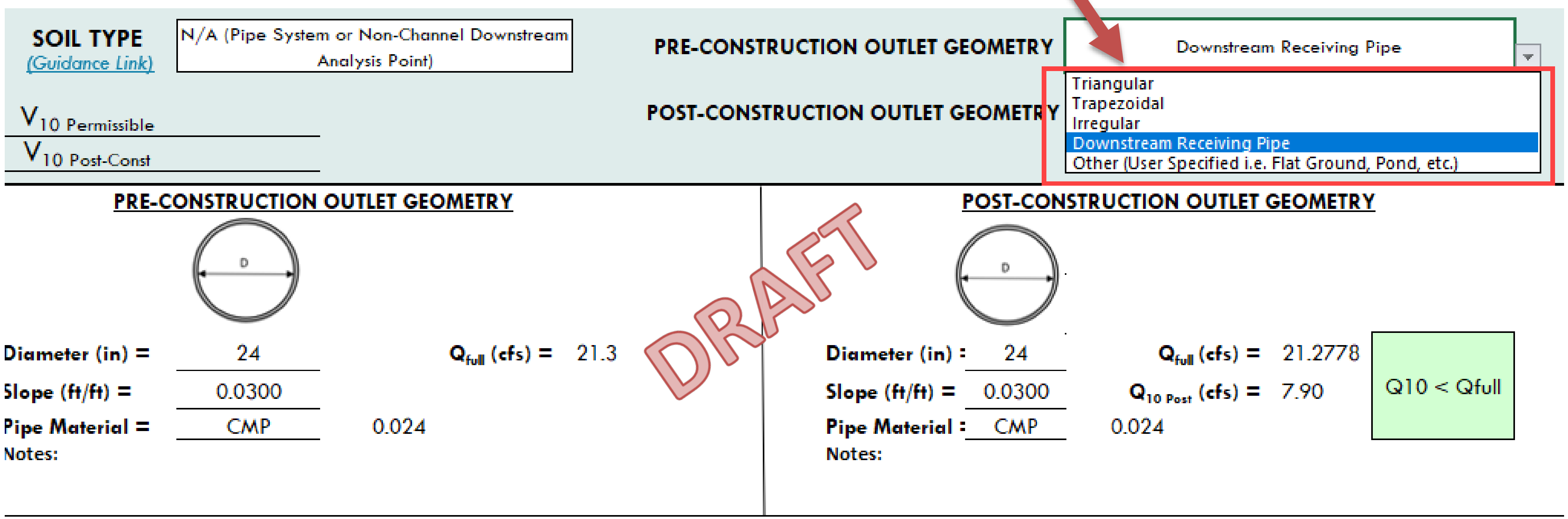
Post-Construction Drainage Area Inputs Pop-Up Form



Individual Outlet Analysis Tab - Geometry Selections

Many Different Geometry Selections are available.

- Automatically updated geometry graphics
- Example below: tying to a private drainage system pipe



Individual Outlet Analysis Tab – Summary & Photos (Page. 2)

SUMMARY

Please provide a summary of the outlet analysis here. If downstream improvements are needed please describe them and why they are required. If no downstream improvements are proposed please explain why the changes in discharge are allowable without improvements. If ponds are present downstream please provide a description of their condition with photos included below.

OUTLET SITE PHOTOS

NUMBER OF OUTLET PHOTO PAGES	2

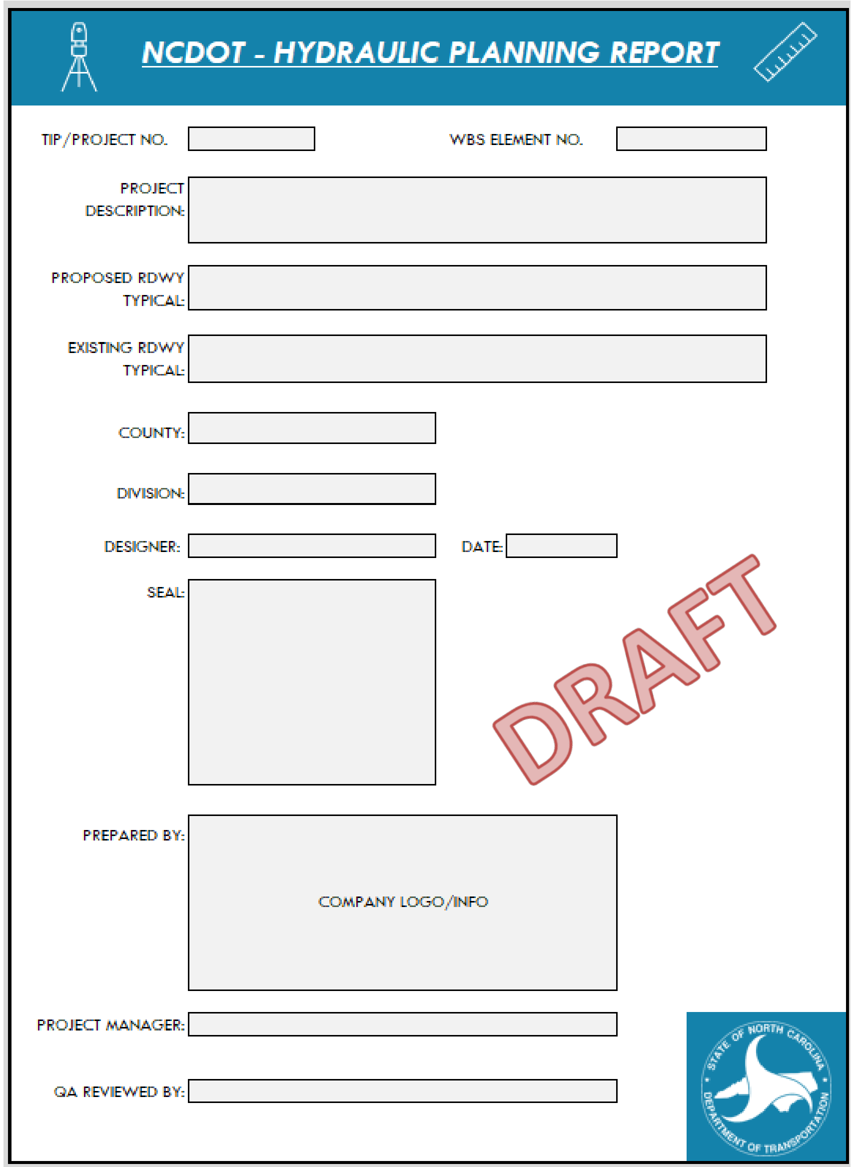
Noteworthy Features:

- Drop down that automatically adds more photo pages
- Summary guidance

Hydraulic Planning Report (HPR) Tool

- **Major Crossings & Risk Identified Early**
  - PDN Stage 2HY1 – Preliminary Hydraulic Recommendations
  - Consolidate required information into one spreadsheet – minimizing report size
  - Utilizes Macros to Improve User Experience
- **Stormwater Management Plan Treatment Goals Identified Early**
  - PDN Stage 2HY1 –Preliminary Stormwater Management Plan (pSMP) is included
- **Printing and Photo Page Tools**
  - Same functionality as outlet analysis tool
- **Improved Guidance on Filling Out Cells**
  - Information pop-up windows and data validation cell notes
- **Potential Future ATLAS Tool Compatibility**

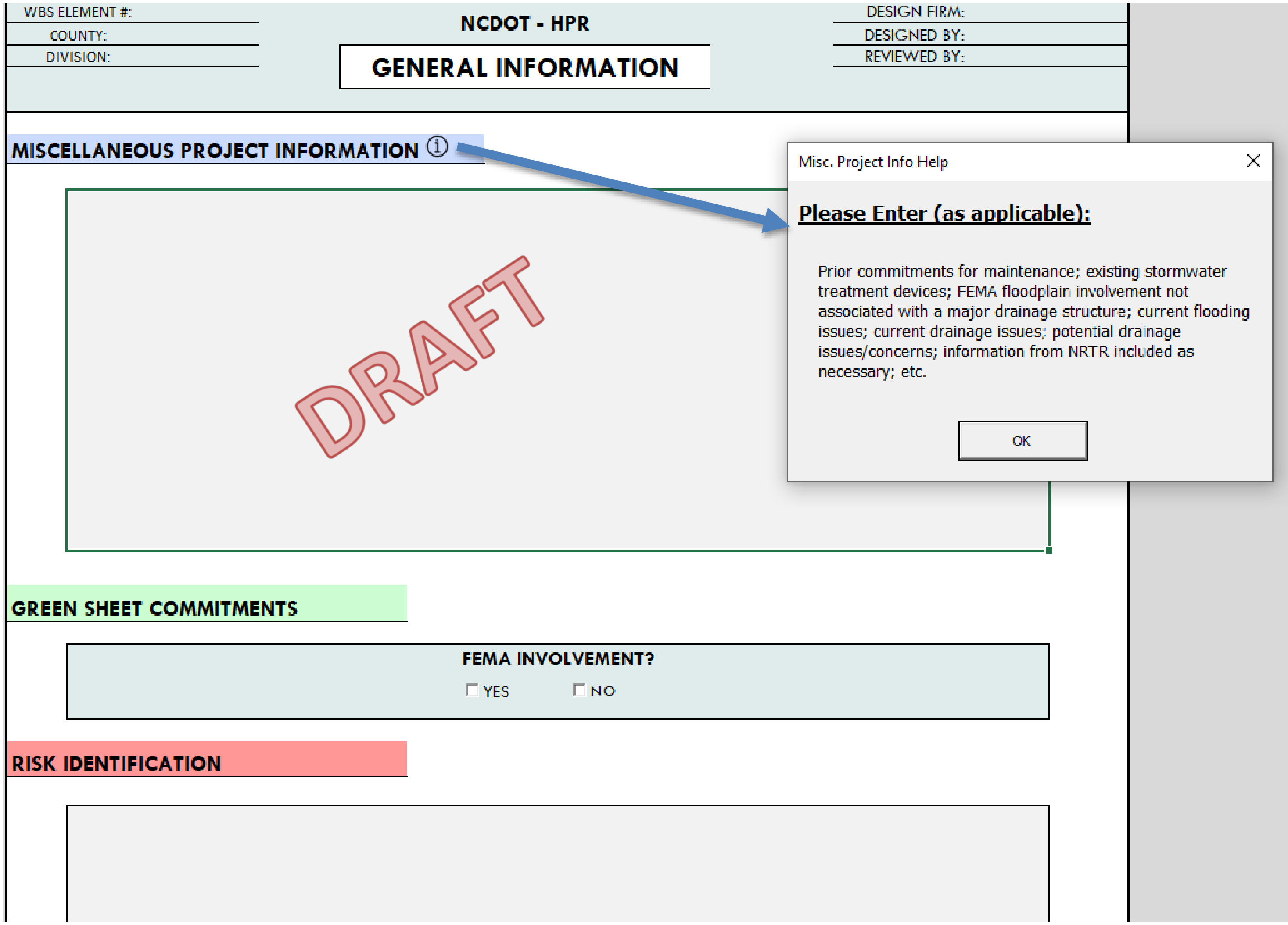
HPR – Cover Page and Printing Buttons



NCDOT - HYDRAULIC PLANNING REPORT

TIP/PROJECT NO.
WBS ELEMENT NO.
PROJECT DESCRIPTION:
PROPOSED RDWY TYPICAL:
EXISTING RDWY TYPICAL:
COUNTY:
DIVISION:
DESIGNER:
DATE:
SEAL:
DRAFT
PREPARED BY:
COMPANY LOGO/INFO
PROJECT MANAGER:
QA REVIEWED BY:
STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

HPR – General Info & Pop-Up Guidance



HPR – Major Crossings Table

PROJECT NUMBER:
WBS ELEMENT #:
COUNTY:
DIVISION:

PRELIMINARY HYDRAULIC RECOMMENDATIONS FOR MAJOR CROSSINGS

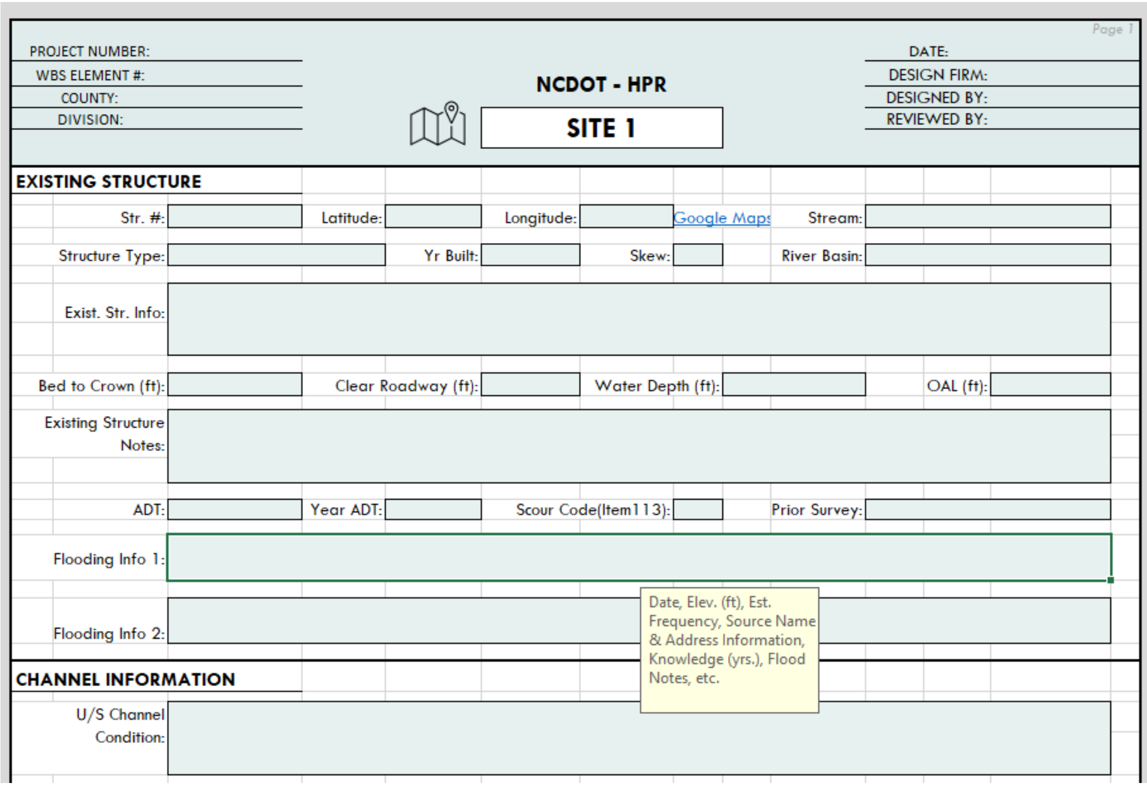
DATE:
DESIGN FIRM:
DESIGNED BY:
REVIEWED BY:

SITE NUMBER	ALTERNATIVE ID (2)	ROUTE	STATION	LAT	LONG	STREAM/ WETLAND ID	STREAM NAME	FEMA STUDY TYPE	DRAINAGE AREA (Mi^2)	EXISTING STRUCTURE	MINIMUM RECOMMENDED STRUCTURE	Notes
										Number, Size, Structure Type	Number, Size, Structure Type	

NOTES:
(1) Major Crossings - conveyance greater than 30 square feet or more.
(2) Complete Table for all Roadway projects (Not necessary for Structure replacement projects)
(3) Provided in planning document
(4) Mark N/A for Site No. if no major drainage structures.

- Macro button to add/delete rows
- Button to automatically create and name individual tabs for each Site

HPR – Site Data


Page 1

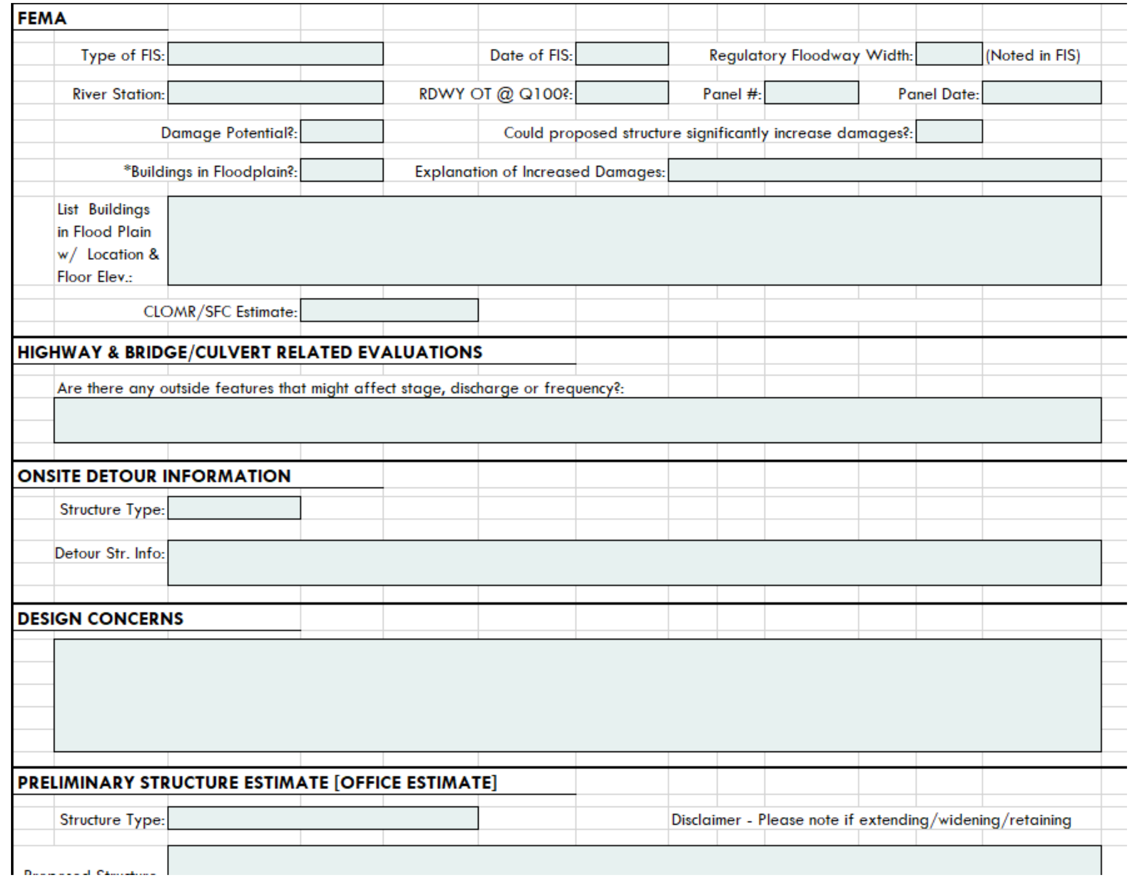
PROJECT NUMBER:
WBS ELEMENT #:
COUNTY:
DIVISION:

NCDOT - HPR
SITE 1

DATE:
DESIGN FIRM:
DESIGNED BY:
REVIEWED BY:

EXISTING STRUCTURE
Str. #:
Latitude:
Longitude:
Google Maps
Stream:
Structure Type:
Yr Built:
Skew:
River Basin:
Exist. Str. Info:
Bed to Crown (ft):
Clear Roadway (ft):
Water Depth (ft):
OAL (ft):
Existing Structure Notes:
ADT:
Year ADT:
Scour Code(Item113):
Prior Survey:
Flooding Info 1:
Date, Elev. (ft), Est. Frequency, Source Name & Address Information, Knowledge (yrs.), Flood Notes, etc.
Flooding Info 2:

CHANNEL INFORMATION
U/S Channel Condition:


FEMA
Type of FIS:
Date of FIS:
Regulatory Floodway Width:
(Noted in FIS)
River Station:
RDWY OT @ Q100?:
Panel #:
Panel Date:
Damage Potential?:
Could proposed structure significantly increase damages?:
*Buildings in Floodplain?:
Explanation of Increased Damages:
List Buildings in Flood Plain w/ Location & Floor Elev.:
CLOMR/SFC Estimate:

HIGHWAY & BRIDGE/CULVERT RELATED EVALUATIONS
Are there any outside features that might affect stage, discharge or frequency?:

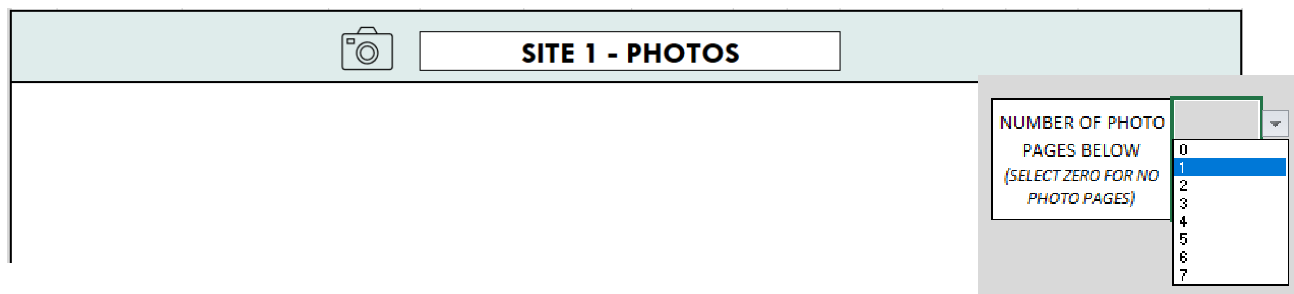
ONSITE DETOUR INFORMATION
Structure Type:
Detour Str. Info:

DESIGN CONCERNS

PRELIMINARY STRUCTURE ESTIMATE [OFFICE ESTIMATE]
Structure Type:
Disclaimer - Please note if extending/widening/retaining

Noteworthy Features:

- Cell notes
- Color theme and project header
- Automatically generated photo pages


SITE 1 - PHOTOS

NUMBER OF PHOTO PAGES BELOW
(SELECT ZERO FOR NO PHOTO PAGES)

0
1
2
3
4
5
6
7

Sea Level Rise Studies - Description

- Probabilistic Sea Level Rise Study over the next 50 Years for Swansboro and Wilmington
- Provides a probabilistic description of water level hazards including sea level rise and storm surge as a planning basis for NCDOT

Sea Level Rise Studies - Goals

- Determine the probabilistic likelihood of floods reaching a range of elevations throughout the next 50 years.
- Account for the random variability of storm surge events as well as the significant epistemic uncertainty in the sea level rise projections.

Sea Level Rise Studies - Process

- Gather relevant storm surge and sea level rise data and past studies
- Identify the best available probabilistic description of storm surge for each location
- Convolve surge data with sea level rise projections using Monte Carlo Simulations
- Produce a probability model for total water level including effects of tide, storm surge and sea level rise that varies in time for the next 50 years

Sea Level Rise Studies - Results

Evolution of Annual Flood Risk Over Time - K14 RCP4.5 – Swansboro Bridge

Site Grade Level [ft NAVD88]	Annual Likelihood of Flooding								
	2020	2030	2040	2050	2060	2070	2080	2090	2100
6.0	6.7%	7.8%	9.2%	11.8%	15.8%	21.7%	28.9%	38.6%	49.0%
6.5	5.3%	6.1%	7.2%	8.6%	11.1%	14.8%	20.1%	26.6%	35.1%
7.0	4.2%	4.9%	5.7%	6.7%	8.1%	10.6%	14.0%	18.8%	24.7%
7.5	3.5%	3.9%	4.5%	5.3%	6.3%	7.9%	10.1%	13.3%	17.7%
8.0	2.9%	3.2%	3.7%	4.2%	5.0%	6.0%	7.5%	9.6%	12.9%
8.5	2.4%	2.7%	3.1%	3.5%	4.0%	4.7%	5.8%	7.3%	9.3%
9.0	2.0%	2.3%	2.6%	2.9%	3.3%	3.8%	4.6%	5.7%	7.0%
9.5	1.7%	1.9%	2.1%	2.4%	2.7%	3.1%	3.7%	4.4%	5.5%
10.0	1.4%	1.6%	1.8%	2.0%	2.3%	2.6%	3.0%	3.5%	4.3%
10.5	1.2%	1.3%	1.5%	1.7%	1.9%	2.2%	2.5%	2.9%	3.4%
11.0	1.0%	1.1%	1.2%	1.4%	1.6%	1.8%	2.1%	2.4%	2.8%
11.5	0.7%	0.8%	1.0%	1.2%	1.3%	1.5%	1.7%	2.0%	2.3%
12.0	0.6%	0.7%	0.8%	0.9%	1.1%	1.2%	1.4%	1.6%	1.9%
12.5	0.4%	0.5%	0.6%	0.7%	0.9%	1.0%	1.2%	1.4%	1.5%
13.0	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%	1.0%	1.1%	1.3%
13.5	0.3%	0.3%	0.4%	0.4%	0.5%	0.6%	0.8%	0.9%	1.0%
14.0	0.2%	0.2%	0.3%	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%
14.5	0.1%	0.2%	0.2%	0.3%	0.3%	0.4%	0.5%	0.6%	0.7%
15.0	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.4%	0.4%	0.5%

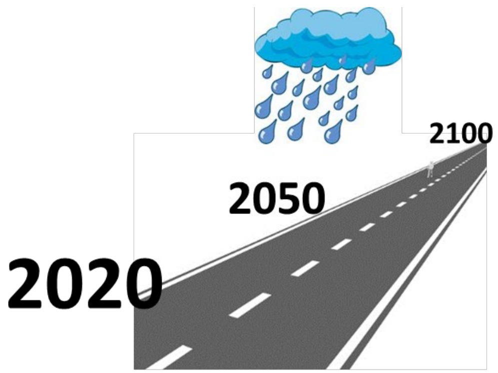
Sea Level Rise Studies - Results

Evolution of Annual Flood Risk Over Time - K14 RCP4.5 - Wilmington

Site Grade Level [ft NAVD88]	Annual Likelihood of Flooding								
	2020	2030	2040	2050	2060	2070	2080	2090	2100
6.0	10.9%	12.4%	14.3%	16.6%	19.8%	23.6%	28.7%	34.1%	41.0%
6.5	8.1%	9.1%	10.4%	12.2%	14.5%	17.2%	20.9%	25.2%	30.4%
7.0	6.2%	6.9%	7.9%	9.0%	10.6%	12.6%	15.3%	18.5%	22.7%
7.5	4.7%	5.3%	6.0%	6.8%	8.0%	9.3%	11.3%	13.7%	17.1%
8.0	3.5%	4.0%	4.6%	5.2%	6.1%	7.0%	8.5%	10.2%	12.7%
8.5	2.5%	2.9%	3.4%	3.9%	4.6%	5.3%	6.4%	7.7%	9.5%
9.0	1.7%	2.0%	2.4%	2.8%	3.4%	4.0%	4.8%	5.8%	7.2%
9.5	1.2%	1.4%	1.7%	2.0%	2.4%	2.9%	3.5%	4.3%	5.4%
10.0	0.9%	1.0%	1.2%	1.4%	1.7%	2.1%	2.5%	3.1%	4.1%
10.5	0.6%	0.7%	0.9%	1.0%	1.2%	1.5%	1.8%	2.3%	3.0%
11.0	0.4%	0.5%	0.6%	0.7%	0.9%	1.0%	1.3%	1.6%	2.2%
11.5	0.3%	0.4%	0.4%	0.5%	0.6%	0.7%	0.9%	1.2%	1.6%
12.0	0.2%	0.3%	0.3%	0.4%	0.4%	0.5%	0.7%	0.8%	1.1%
12.5	0.2%	0.2%	0.2%	0.3%	0.3%	0.4%	0.5%	0.6%	0.8%
13.0	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.3%	0.4%	0.6%
13.5	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.3%	0.4%
14.0	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%
14.5	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%
15.0	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%

New Rainfall Design Development

1. Develop IDF and DDF Curves that address Non-Stationarity.



2. Develop an understanding of the magnitude of future extreme events.

Geophysical Research Letters

RESEARCH LETTER
10.1029/2019GL083235

U.S. Hydrologic Design Standards Insufficient Due to Large Increases in Frequency of Rainfall Extremes

Daniel B. Wright[1], Christopher D. Bosma[1], and Tania Lopez-Cantu[2]

[1]Department of Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, WI, USA,
[2]Department of Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh, PA, USA

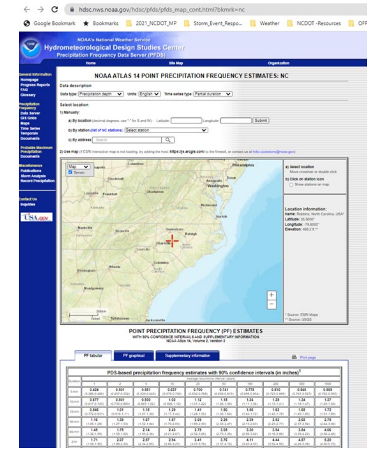
Key Points:
- Conventional analyses neglect trends in extreme rainfall events such as the 100-year storm, which are critical for engineering design
- A regional aggregation approach reveals significant trends in very extreme rainfall in the United States, mainly due to climate warming
- Existing hydrologic infrastructure and analyses in much of the United States may be underperforming due to increases in storm activity

Supporting Information:
- Supporting Information S1

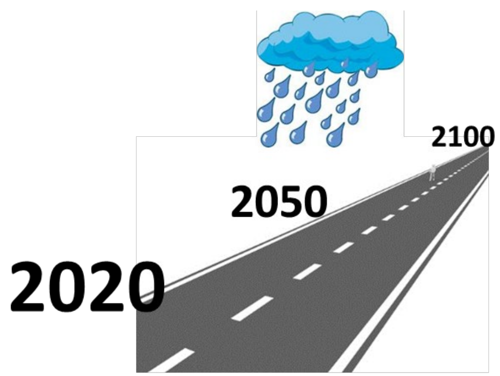
Correspondence to:
D. B. Wright,
danielb.wright@wisc.edu

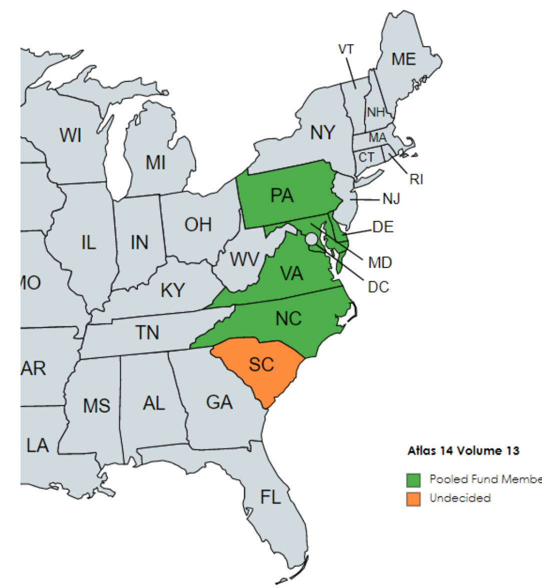
Abstract Evidence for intensifying rainfall extremes has not translated into "actionable" information needed by engineers and risk analysts, who are often concerned with very rare events such as "100-year storms." Low signal-to-noise associated with such events makes trend detection nearly impossible using conventional methods. We use a regional aggregation approach to boost this signal-to-noise, showing that such storms have increased in frequency over much of the conterminous United States since 1950, a period characterized by widespread hydrologic infrastructure development. Most of these increases can be attributed to secular climate change rather than climate variability, and we demonstrate potentially serious implications for the reliability of existing and planned hydrologic infrastructure and analyses. Though trends in rainfall extremes have not yet translated into observable increases in flood risks, these results nonetheless point to the need for prompt updating of hydrologic design standards, taking into consideration recent changes in extreme rainfall properties.

Historic Rainfall Update



- Atlas 14 Volume 13 (six states)
- Atlas 15 – Entire US
  - Non-stationarity/Climate Adaptation





Collaboration between engineers and climate scientists will be a critical step towards determining the best options for adaptation and resilience.

NC DOT is partnering with a team of climate scientists at NCSU to consider how **rainfall extremes** may change in a **warmer climate**.

1. NCSU is focused on **unique comparison** of best available climate model data **to update Intensity, Duration, and Frequency (IDF) Curves**.

2. NCSU is using atmospheric models to develop **future design storms (Hurricanes)** for **stress testing** NC roads and highways

NORTH CAROLINA STATE UNIVERSITY
NC STATE UNIVERSITY

Do different methods give similar results?

Increasing our confidence in how “rainfall extremes” may evolve in a warmer climate

Method 1:
Different
Statistically Downscaled
GCM
Climate Change Projections

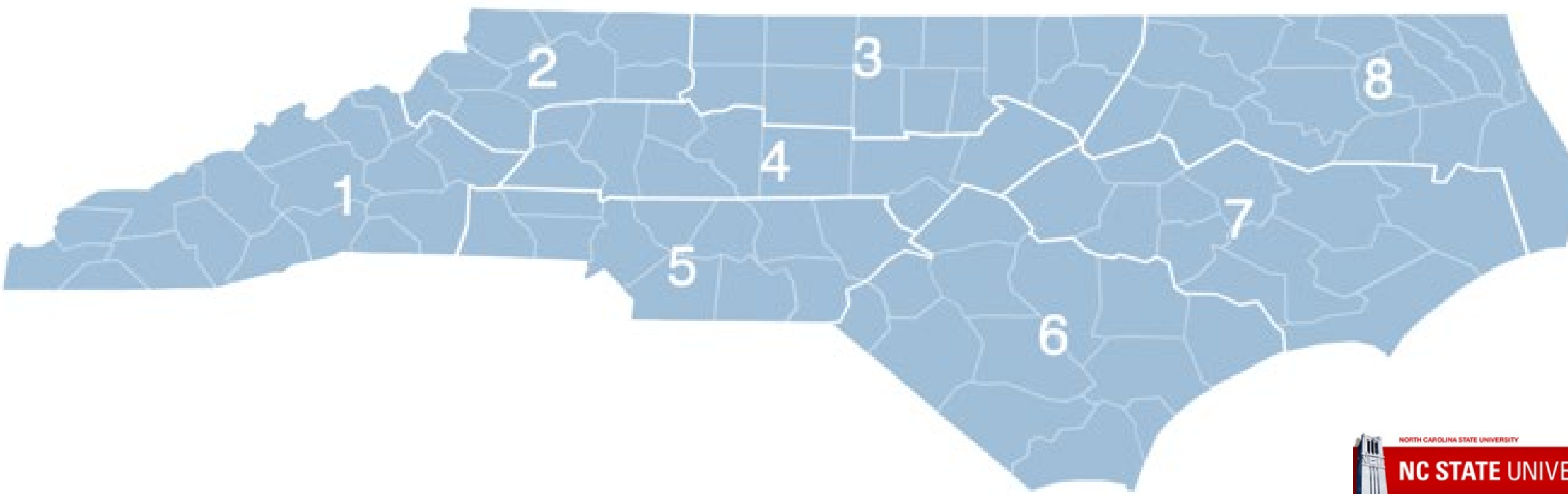
Method 2:
Different
Dynamically Downscaled
GCM
Climate Change Projections

Method 3:
Model experiments that address important limitations (Design Storm - Model Hurricanes)
From method 1 & 2

Develop IDF curves for all points and aggregate to climate divisions to better estimate the regional signal for each downscaled GCM and method

Mid-century & End-century
(2041-2069; 2070-2099)

Return Periods
(2yr, 10yr, 25yr, 50yr, 100yr)



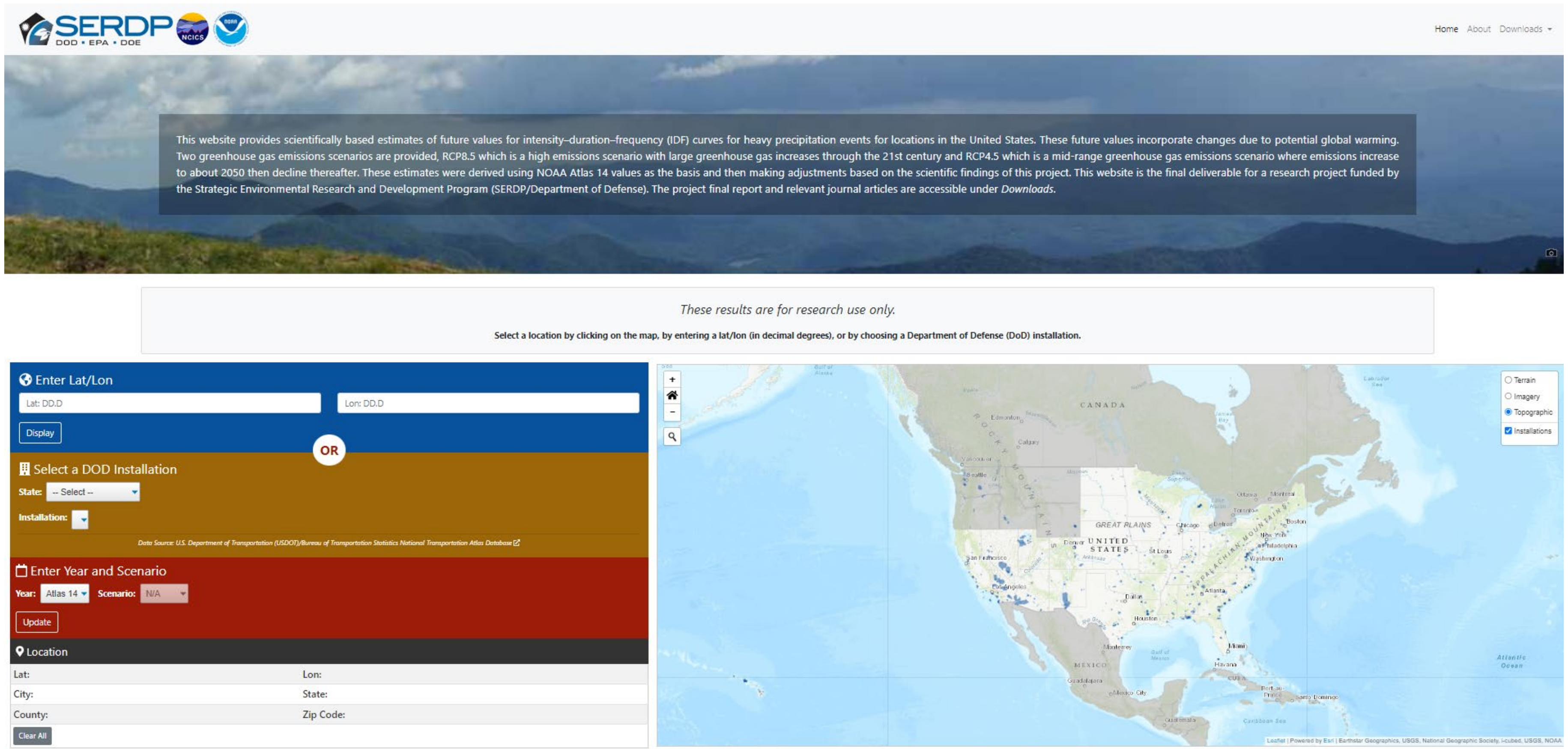
NC STATE UNIVERSITY

Preliminary results indicate…

- By end-century; large changes may be anticipated under a high greenhouse gas emission scenario.
- In almost all instances suggests plausible adjustments to IDF curves:
  - Future 10yr storm exceeds the historical 25 year storm
  - Future 25yr storm exceeds the historical 50 year storm
  - Future 50yr storm exceeds the historical 100 year storm
  - Future 100yr storm exceeds the historical 500yr storm

Existing Non-Stationarity IDF Tool

https://precipitationfrequency.ncics.org/

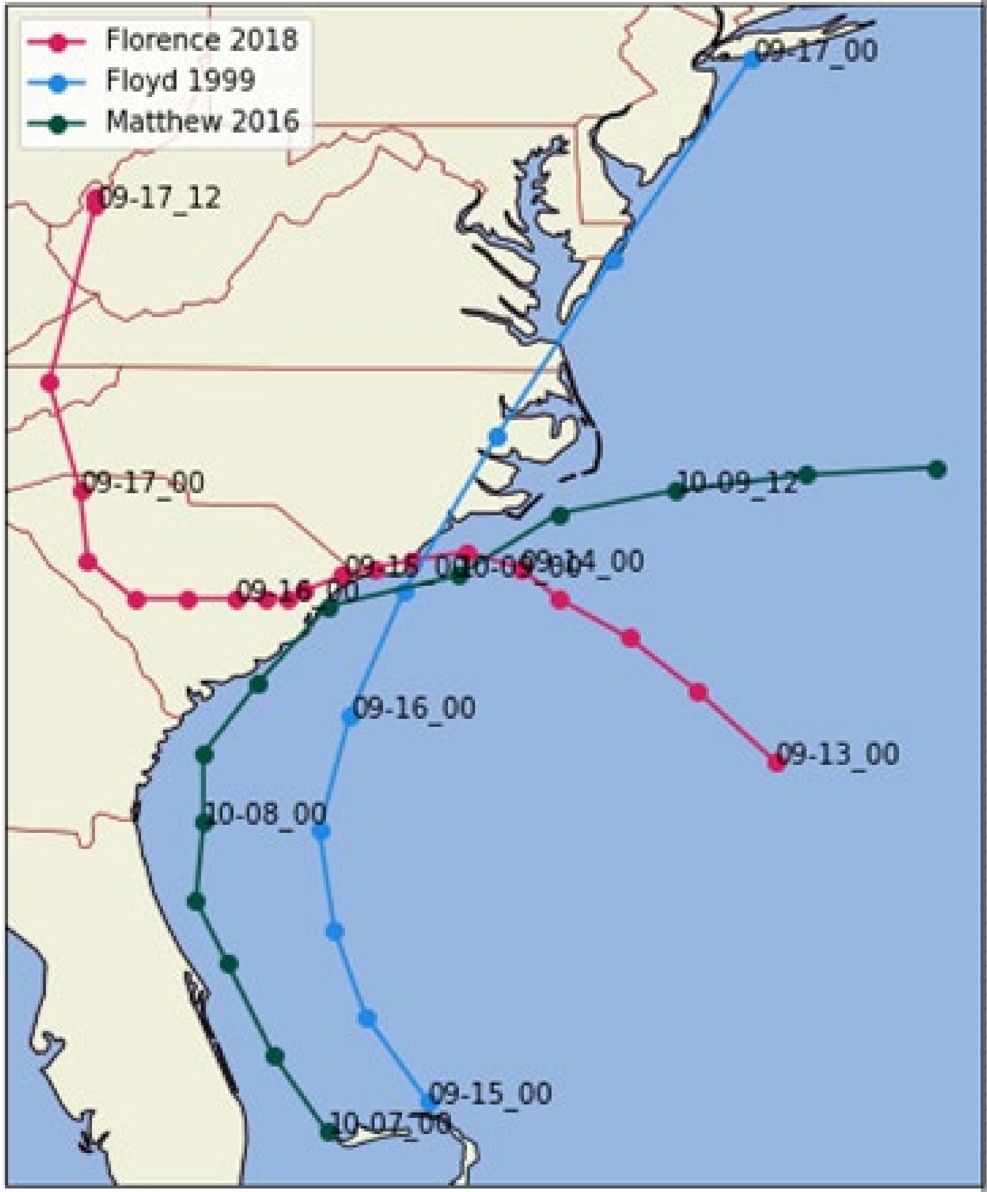


NC STATE UNIVERSITY

Pseudo Global Warming Models- WRF

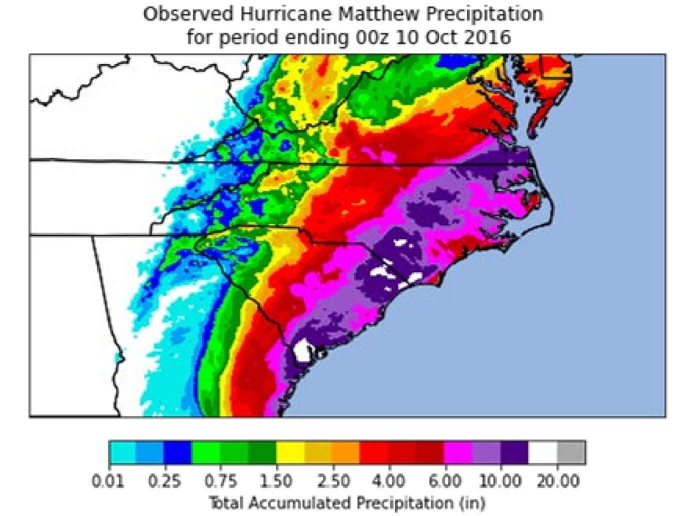
- Goal: Examine a variety of events
  - 3 very impactful hurricanes for eastern NC
    - high rainfall totals, flooded/washed out roads
- Diverse tracks and precipitation forcing
  - Tracks:
    - one stalled (Florence)
    - one moved very quickly (Floyd)
    - one only grazed NC (Matthew)
  - Storm characteristics
    - purely tropical (Florence)
    - Midlatitude interactions (Floyd, Matthew)

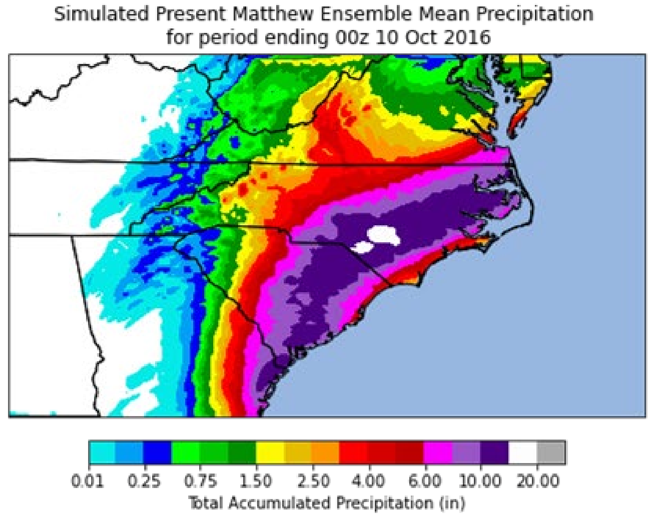
Hurricane Cases



Matthew precipitation, total ending 00 UTC 10 Oct 2016

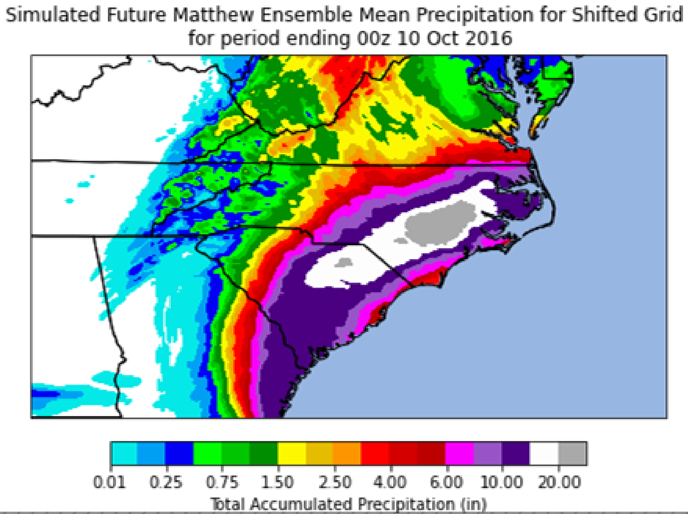
Observed Matthew (storm total, inches)





Present ensemble mean simulation

Future ensemble mean simulation



Present ensemble:

- Credible rainfall pattern, captures extrema

Future ensemble mean:

- Substantial expansion of 15"+ isohyet

NC STATE UNIVERSITY

Summary of Future Simulation Changes and Ongoing Simulations

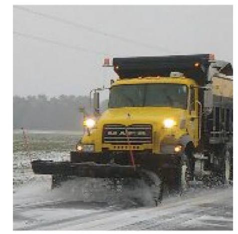
- Future Hurricane Matthew indicates:
    - >50% increase in total precipitation
    - >100% increase in the frequency and coverage of intense rain rates exceeding 1.5 inches per hour

- Also simulated Hurricanes Floyd and Florence that created significant flooding within eastern NC. Preliminary results indicate similar and in some cases larger increases. For instance, > 75% increase in total precipitation with Hurricane Florence.

NORTH CAROLINA STATE UNIVERSITY
NC STATE UNIVERSITY

NORTH CAROLINA
Department of Transportation




2D Modeling

January 2023

2D Modeling Projects

- Alligator River – Hydrodynamic Modeling
- NC 197 – SRH2D
- Knott's Island – Hydrodynamic and SRH2D
- I-40 Burgaw – HECRAS 2D
- US-74 – HECRAS 2D
- I-95 – HECRAS 2D
- Kinston Bypass – HECRAS 2D

Operations Support - STIP Services

- Review
  - Use GESC as first option
  - High profile Projects
  - Design Review
  - High risk project impacts
- Design
  - Small projects
  - Construction revisions

- Scope
  - Major structures
  - Risk
- Manday Estimates
  - Projects
  - Supplements
- Risk Analysis
  - Outfalls
  - Upstream
  - Substandard

Floodplain group

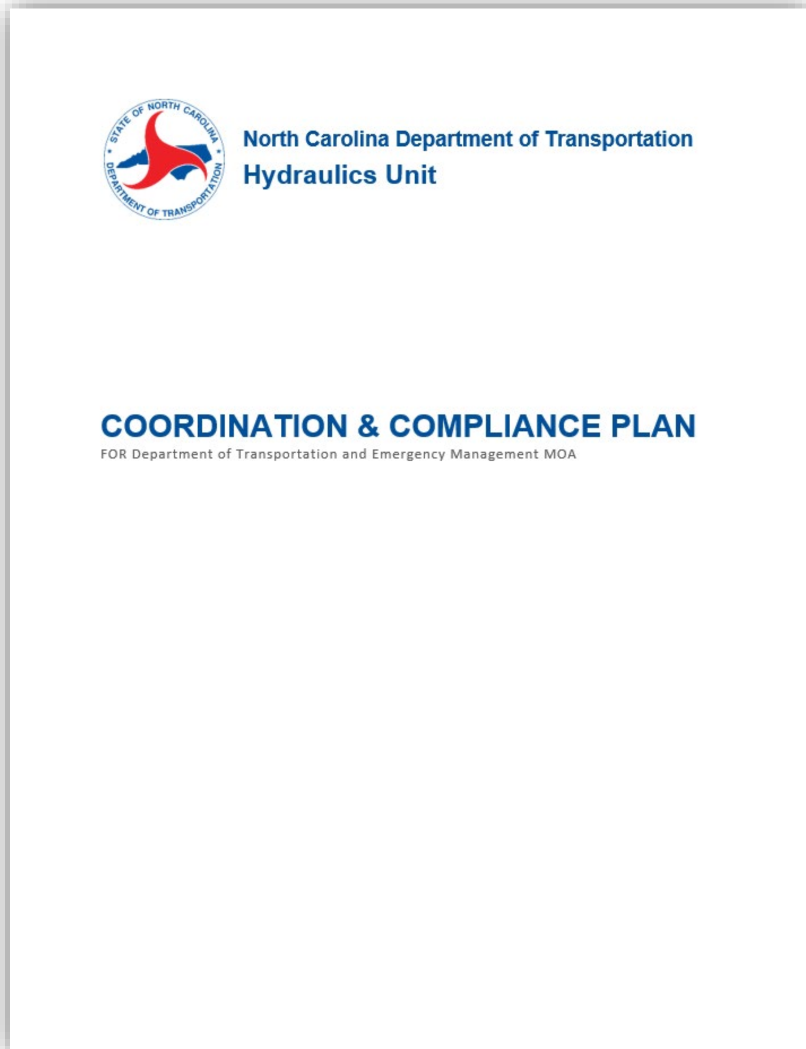
- Manage the Highway Floodplain Program
- Ensure projects meet the State Floodplain Compliance, SFC
- Floodplain Research
- Resilience – Flood Monitoring/Vulnerability Assessments
- Strategic Guidelines Update
- Data Management
- Scour Response
- Website Management

NFIP Compliance

SFC

State Floodplain Compliance

(CCP) COORDINATION & COMPLIANCE PLAN


North Carolina Department of Transportation
Hydraulics Unit

COORDINATION & COMPLIANCE PLAN
FOR Department of Transportation and Emergency Management MOA

- Interagency Coordination and NFIP Compliance will be outlined in the COORDINATION & COMPLIANCE PLAN (CCP)
- Document will be updated as needed

Section 2: Coordination

- Monthly Meetings
- Final As-Builts and LOMR Processing
- Before, During, After Storm
- Training and Program Improvement

Section 3: Technical Guidance

3.1 to 3.2 - Criteria Required for SFC and NFIP Approval

3.3 to 3.5 - Guidelines, Modeling Standards and Common Modeling Issues

3.6 to 3.8 - Deliverables and Submittal Procedures

Contents

Coordination & Compliance Plan for NCDOT/NCEM MOA

Communicate and Manage Program

NFIP Approval

Guidance

GUIDANCE

- Submitting Projects for FEMA Approval
- CLOMR Guidance
- HEC-RAS Modeling - Aluminum Box Culvert
- HEC-RAS Modeling - Bridge Opening
- HEC-RAS Modeling - Bridge Rail
- Information for Highway Divisions - Emergency Drainage Structure Replacement Protocol
- Information for Highway Divisions - Roadway Improvements within FEMA Regulated Floodplains
- MOA Submittals - Common Issues
- MOA Submittals - BFE Comparison Spreadsheet Example
- MOA Submittals - Nomenclature
- MOA Submittals - Package Requirements
- MOA Submittals - Rounding Base Flood Elevations to the Tenth
- MOA Submittals - Type Determination

MOA DOCUMENTS

- Memorandum of Agreement (Modified 8/12/2016)
- FEMA Compliance Process Flowcharts

Criteria Required for SFC and NFIP Approval

- A BFE increase (measured to the hundredths of a foot) that impacts an existing structure located outside of the right-of-way is not allowed under any circumstance.
- In order to achieve NFIP approval, a project must meet the criteria of an SFC Type:

A
B
C

Protocols

The remaining portion of Section 3.2 contains various protocols that were written in previous MOAs between NCDOT/NCEM.

- Sharing data
- Technical Expertise
- Routine and Emergency Maintenance
- Training
- Federal regulations, policies, and guidelines

Guidelines, Standards & Common Issues

- Material originally found in the Common Issues Checklist or NCDOT Connect Hydraulics site
- Made minor updates to correct spelling errors/ update language.
- Typical issues found during review

Deliverables

SFC Project.zip (name following the SFC and HEC-RAS Nomenclature guidance)

Effective Model

- Copy of Effective Model

SFC Model

- Model Files

SFC Files (Forms found on the Hydraulics/FEMA Coordination site)

- **FEMA Coordination Form** (submit as Excel form)
- **Title Sheet or Vicinity Map** (Make sure R/W and Let dates are current)
- **CADD file** (name file: "***yyyymmdd_TIP_SFC.dgn***") Include: existing and proposed roadway alignment, existing and proposed bridge, slope stakes, TOPO (w/any buildings, etc.), contours, stream alignment, and HEC RAS cross-section locations (with sections labeled).
- **TIN file**
- **NCDOT Bridge/Culvert Survey Report** (signed, sealed, and NCDOT-approved)
- **Hydraulic Model Narrative** describe model changes as progression takes place from the Duplicate Effective Model to the Corrective Effective Model (to the Existing Conditions Model if needed) to the Revised Model.
- **Output Comparison Table (Excel format)** Spreadsheet should cover the area from downstream tie to upstream tie. Highlight the maximum WSEL increase or decrease.
- **Parcel/Property Owner Information (CADD file)** (parcel boundary electronic file with deed book & page numbers), Not required for Type A submittals)
- **Documentation of FMP concurrence, if applicable**
- **Other Files, if applicable**

Submittal Procedures

- Prepare SFC Submittal Package and put all the required data in a properly structured and labeled folder.

Submittals

Go to the **NCDOT Hydraulics/FEMA Coordination Team Site** in order to submit SFC, CLOMR, or LOMR packages. Once you have access, the site can be found on Your Team Sites.

Registration is required to access the coordination team site.

To register, please use the button below to e-mail your name and NCID or AD :

Register Login

Chapter 15
Floodplain Management

- Updated language to comply with NFIP regulations and to align with New MOA and CCP
- Removed sections discussed in CCP or other publications, including:
  - SFC(MOA) Types
  - CLOMR/SFC(MOA) Documentation Requirements
  - Rest Area Buildings in Floodplain

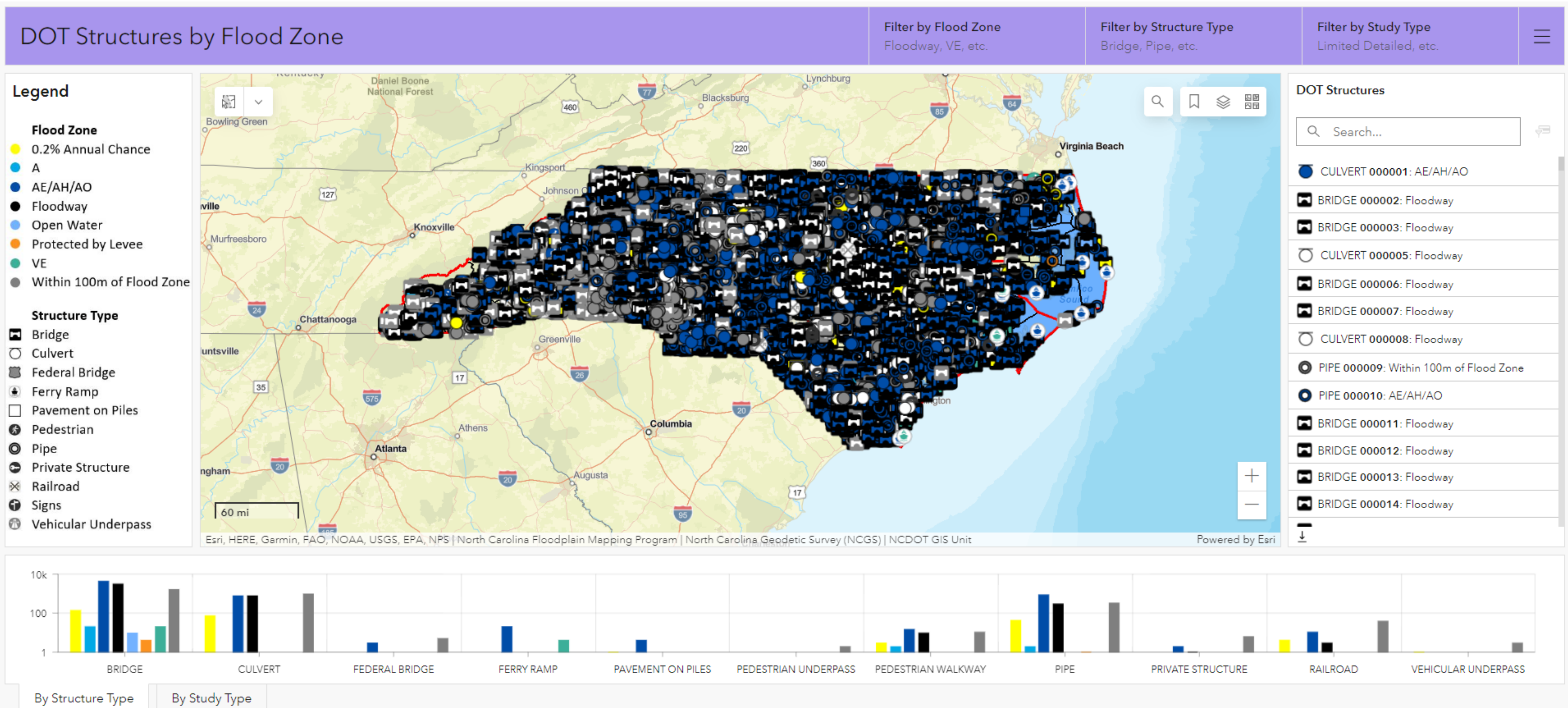
Chapter 15
Floodplain Management

- Updated the section discussing NCDOTs responsibilities when making changes in a Special Flood Hazard Area (SFHA) including Maintenance Culvert Replacement
- Updated the section on the Replacement and Reimbursement of Emergency Flood-Damaged Structures

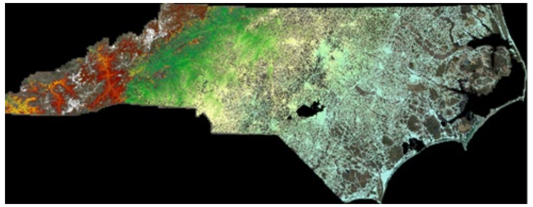
When

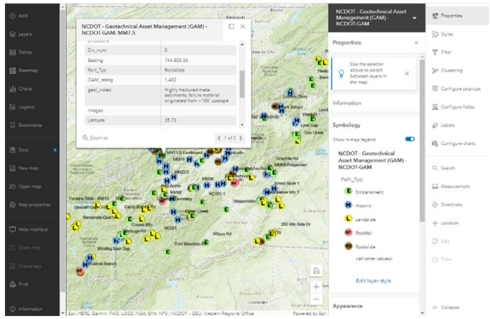
- All project submittals made following JANUARY 1st 2022 shall be reviewed in accordance with this technical guidance
- CPP and 2020 MOA to be posted on website soon.
- Updated Chapter 15 to be released in February

Know your Project Flood Risk

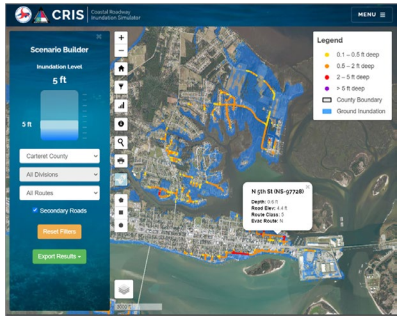


Natural Hazard Risk Tools

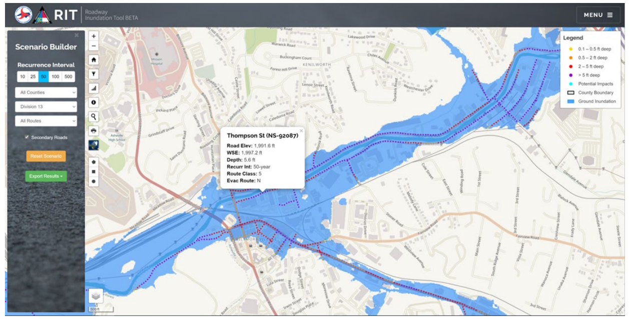




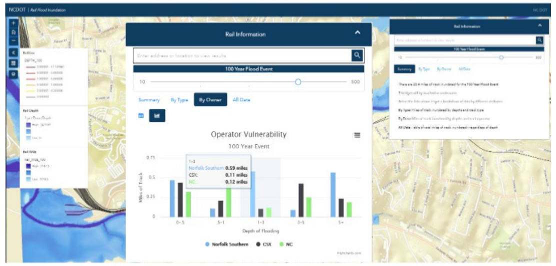
Landslide Risk



Coastal Road
Flood Risk - SLR



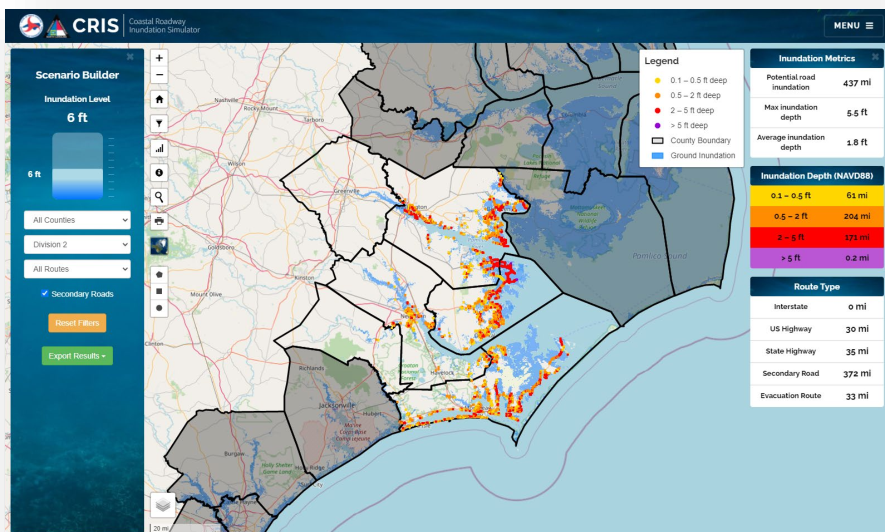
Inland Road
Flood Risk

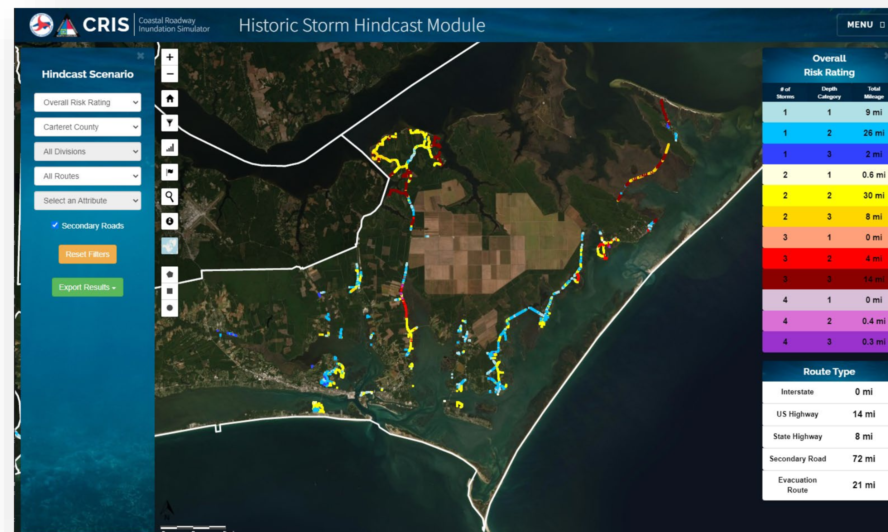


Rail Flood Risk

Coastal Roadway Inundation Simulator (CRIS)

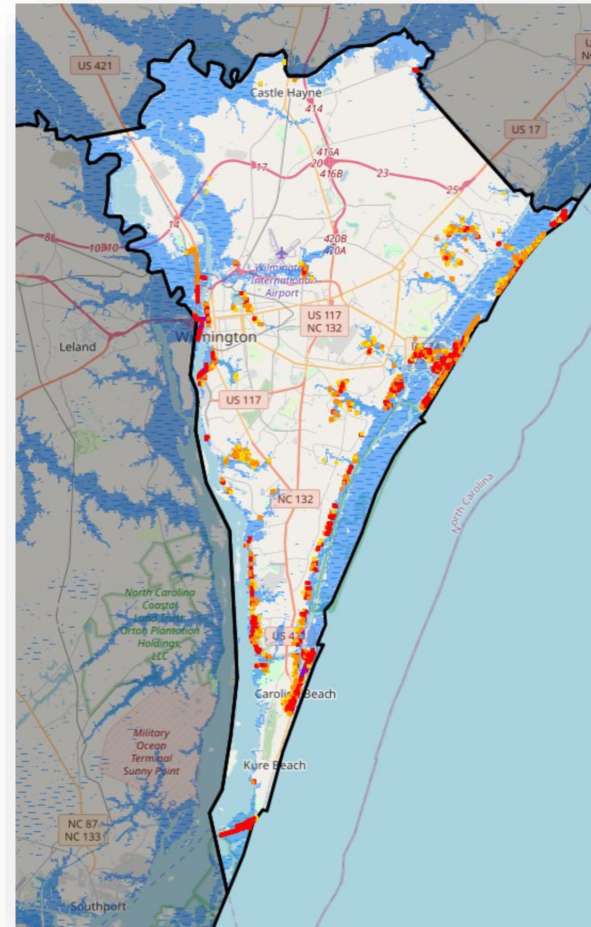
- Predicts impacts of roadway inundation for 23 coastal counties
- Inundation levels range from 1 to 17 feet
- Historic Storm Hindcast Module displays impacts from four past hurricanes





Goals

- Quantify and simulate inundation impacts
- Plan for:
  - Emergency response
  - Evacuation
  - Road closure
  - Future resiliency
- Assist with maintenance of roadway infrastructure



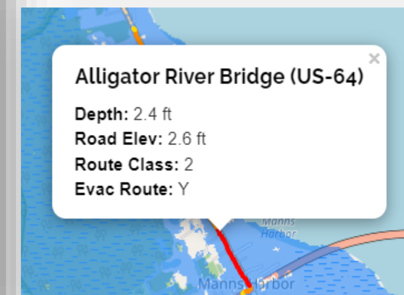
Metrics and Process

- NC QL2 LiDAR (2014-2015) used to assign roadway centerline elevations (NAVD88 FT)
- LiDAR-based modeling used to produce inundation boundaries
- Points were generated every 50 feet along road centerlines
- At each point, roadway elevations were compared to the selected inundation profile to calculate inundation depth
- Mileage statistics determined by multiplying the number of impacted points by 50

Inundation Metrics	
Potential road inundation	71 mi
Max inundation depth	5.9 ft
Average inundation depth	2.1 ft

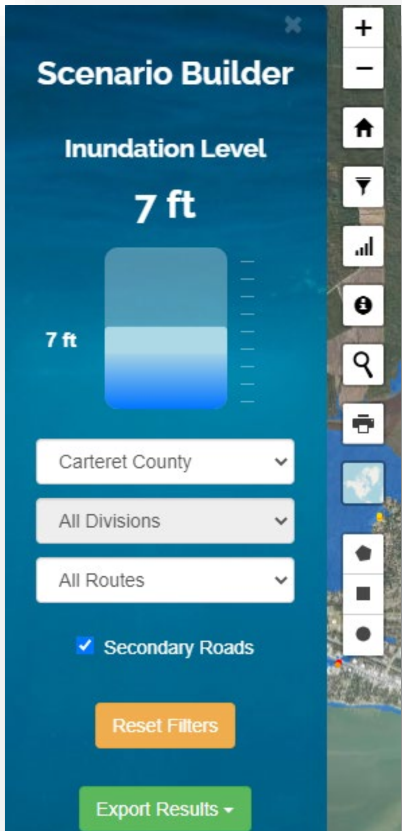
Inundation Depth (NAVD88)	
0.1 – 0.5 ft	7 mi
0.5 – 2 ft	29 mi
2 – 5 ft	34 mi
> 5 ft	0.5 mi

Route Type	
Interstate	0 mi
US Highway	10 mi
State Highway	0 mi
Secondary Road	61 mi
Evacuation Route	10 mi

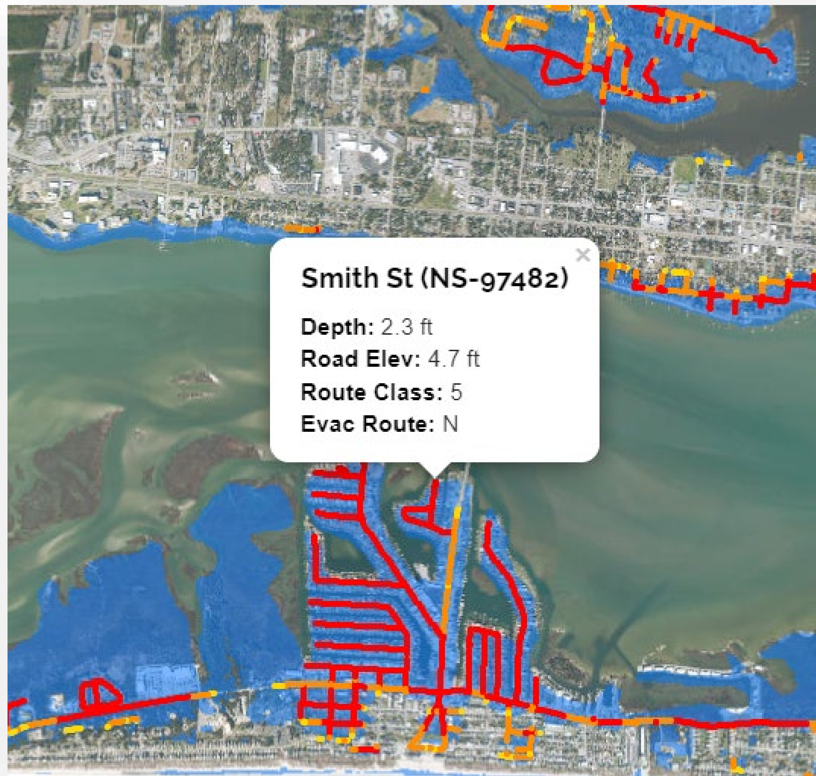


Examples and Results

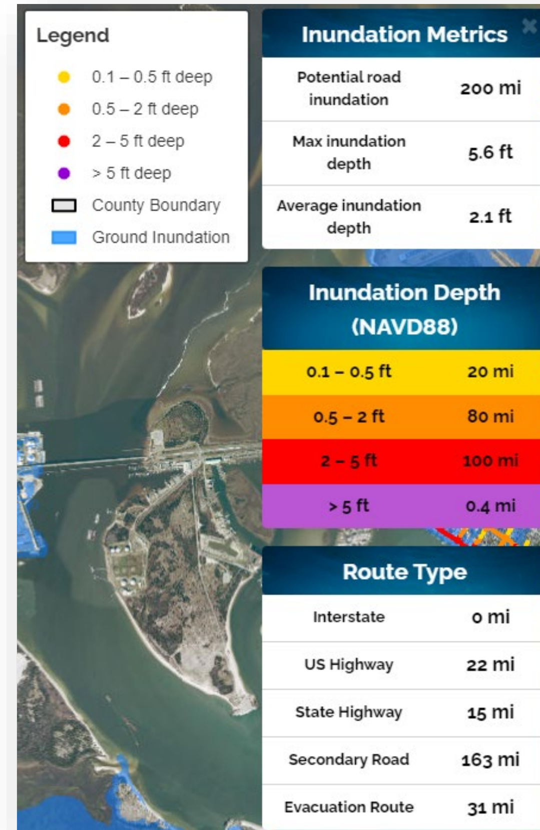
1. A scenario is built



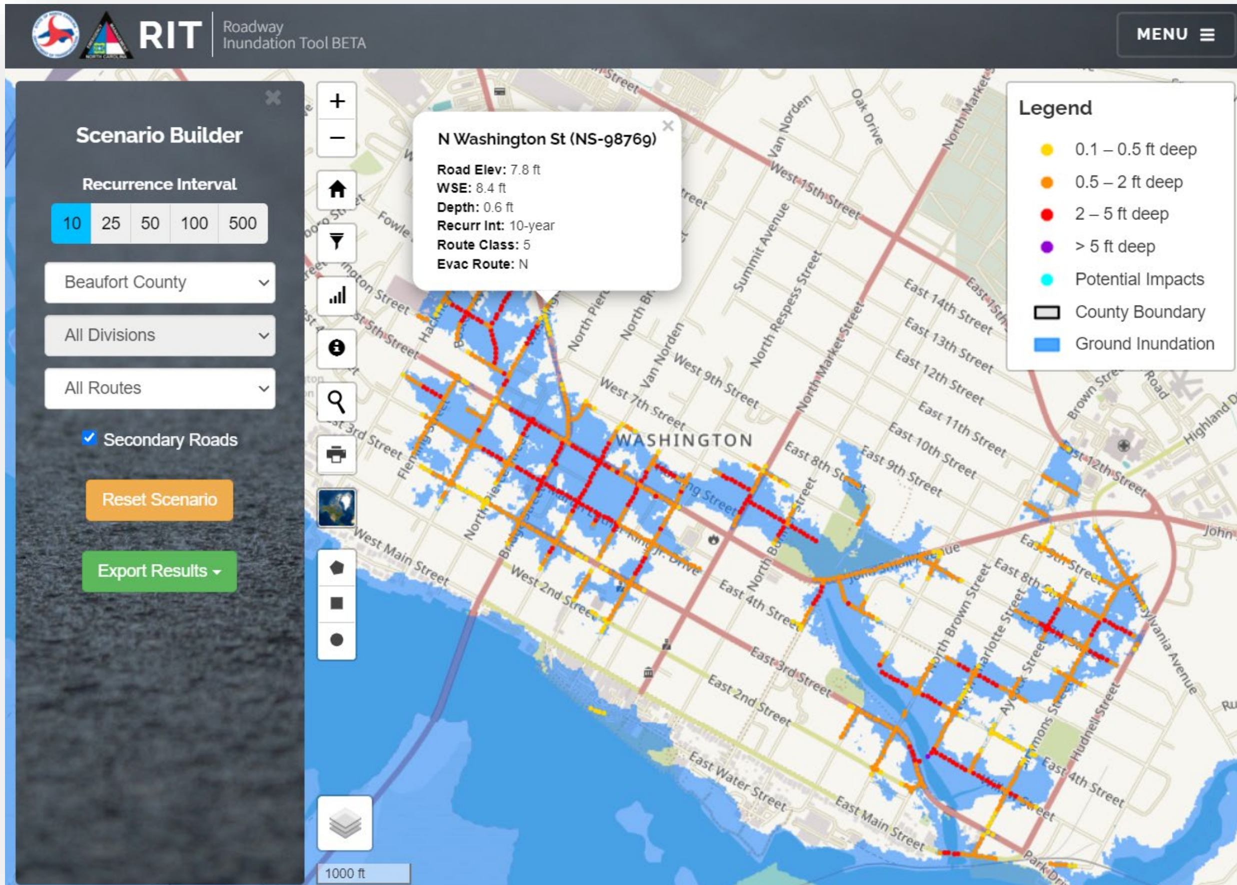
2. Roadway points and inundation tiles are generated



3. Metrics are calculated and displayed



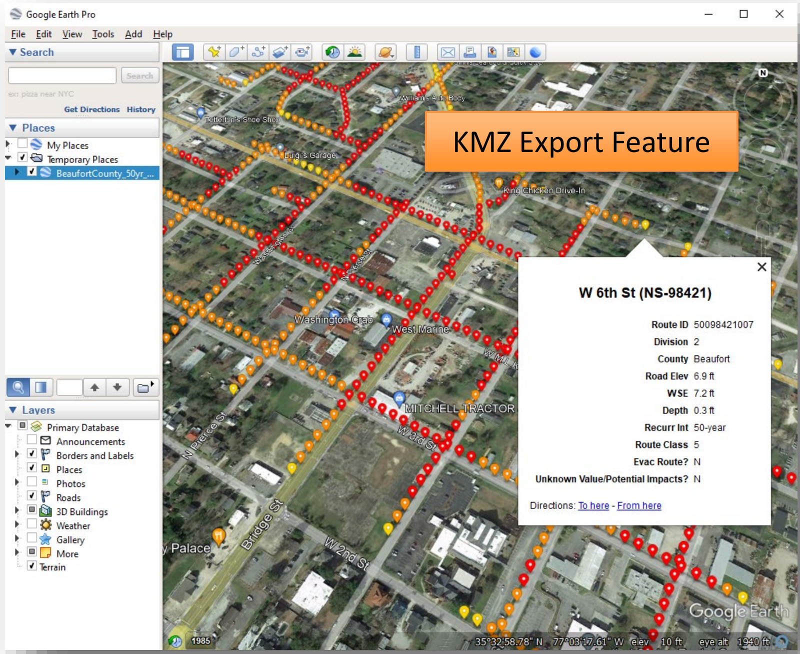
Roadway Inundation Tool (RIT)

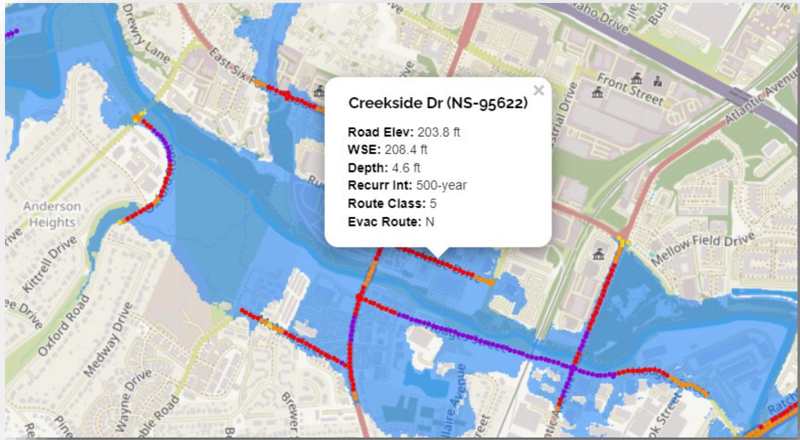


- Based on multi-frequency riverine flood studies
  - 10-, 25-, 50-, 100- and 500-year recurrence intervals
- Statewide coverage
- Primary and secondary roads
- Originally an ArcGIS Online dashboard
- Built using open-source, scalable technologies

Goals

- Visualize and quantify road inundation
- Help NCDOT plan for:
  - Emergency response
  - Evacuation
  - Road closure
  - Climate change resiliency
- Provide quick, flexible access to data without reliance on GIS software
- Identify roads that may require higher maintenance or eventual replacement

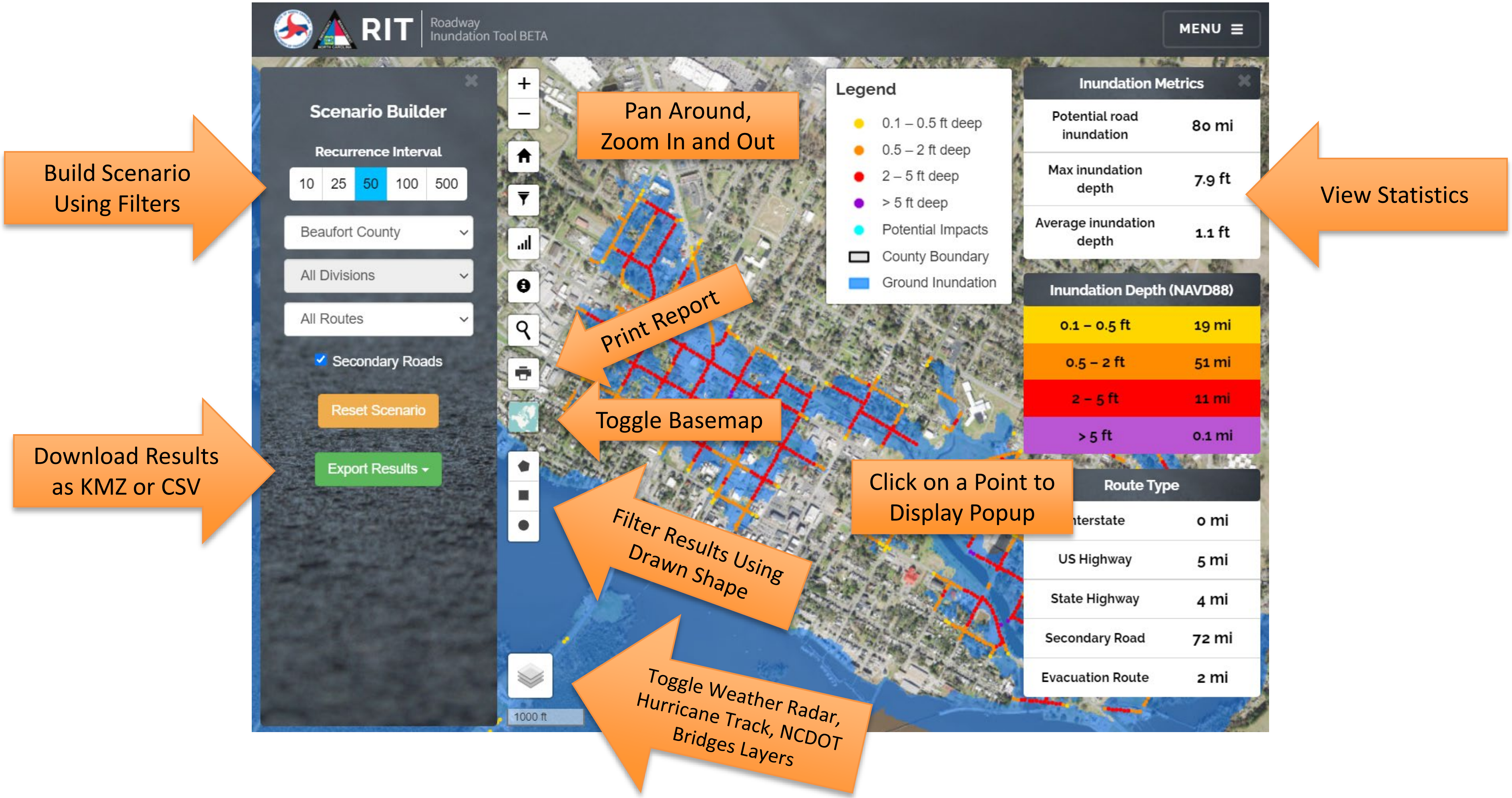




Metrics and Process

- Points were generated every 50 feet along road centerlines
- Each point was assigned a LiDAR-based road elevation (NAVD88 FT) and water surface elevations for each flood recurrence interval
- Water Surface Elevation - Road Elevation = Road Inundation
- User can filter data by recurrence interval, county, NCDOT division, route type and route name
- App displays points that match the filter criteria
- Statistics calculated dynamically based on the selected points
  - Max and average inundation depth
  - Mileage of road impacted by flooding (total and based on route type)

Using the App



Vulnerability Assessments

- US-74
- US-70
- I-87
- I-40 - Western NC

US 74 Vulnerability Study

Team

Project Action Team (PAT)
- NCDOT Hydraulics Unit
- NCDOT TPD
- Supported by Atkins

Technical Advisory Committee (TAC)
- NCDOT Leadership
- NCDOT Div 3,6,8,10
- Charlotte
- Wilmington
- RPOs and MPOs
- FHWA

Study Questions

- How will future traffic be impacted by climate-related events (floods, storms, heat waves)?
- Which infrastructure assets will cause the most disruption when offline?
- Which assets are most important?
- Which critical facilities are most at risk (exposure and condition)?
- Which assets are most isolated?
- How will vulnerable populations be impacted by future climate change in terms of access?

Schedule & Milestones

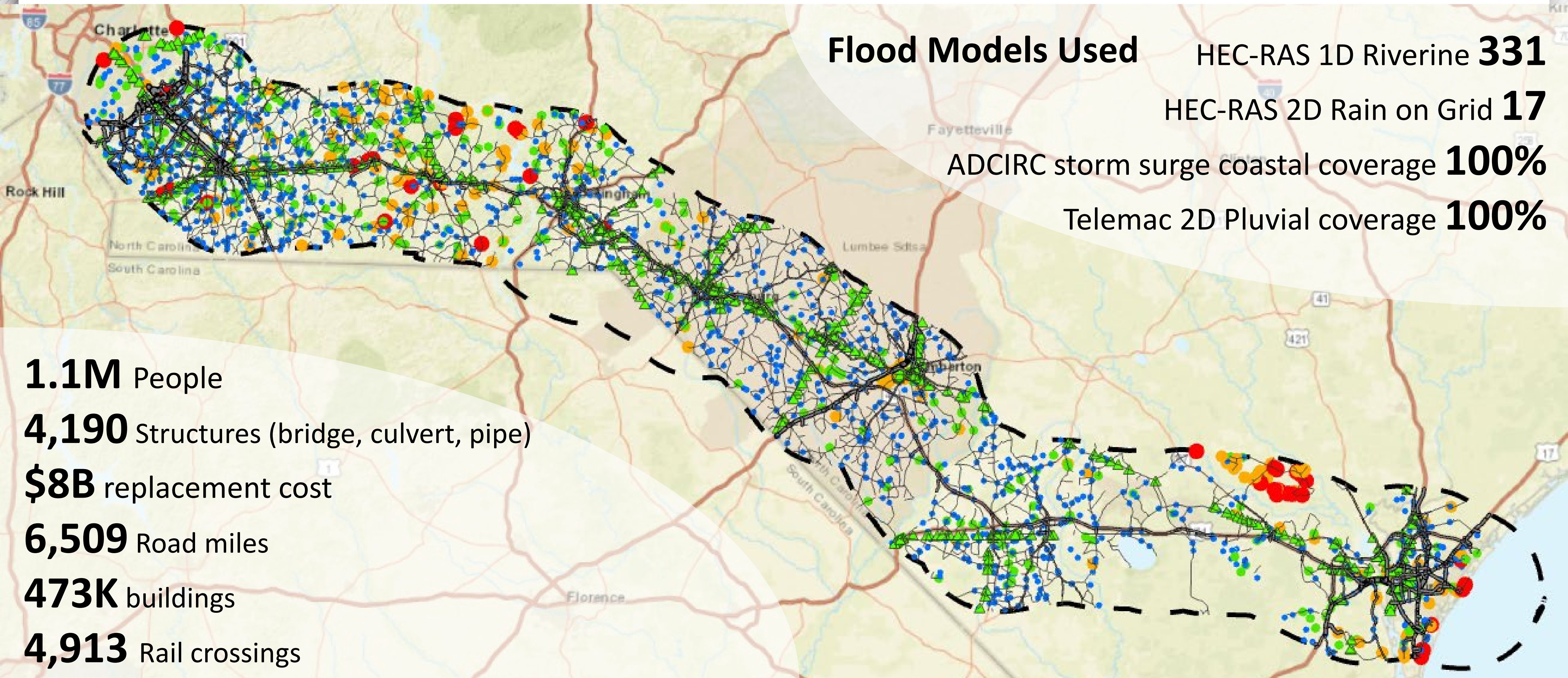
- Time Frame: 8/2021 – 7/2022
- **TAC Workshop 1: 10/12/2021**
  - Intro, Set Goals/objectives
- **TAC Workshop 2: TBD**
  - Baseline Results Presentation
  - Set Adaptation/Mitigation Scenarios
- **TAC Workshop 3: TBD**
  - Scenario Results Presentation
  - Scenarios Modifications
- **TAC Workshop 4: TBD**
  - Scenario Results Presentation
  - Decide recommended actions

Tools and Data

Atkins City Simulator
- Digital Twin of Corridor
- Simulates 2020-2060
- Population Growth
- Travel Demand
- Disadvantaged populations

Leveraging Existing Datasets
- NCDEM Rain-on-grid
- NCDOT state traffic models
- ATLAS Datasets
  - Roads
  - Rail
  - Admin Boundaries
  - Assets
- MPO/RPO Travel Demand Models
- NC OneData Parcels
- …

US 74 Digital Twin



Flood Models Used

HEC-RAS 1D Riverine **331**

HEC-RAS 2D Rain on Grid **17**

ADCIRC storm surge coastal coverage **100%**

Telemac 2D Pluvial coverage **100%**

1.1M People

4,190 Structures (bridge, culvert, pipe)

$8B replacement cost

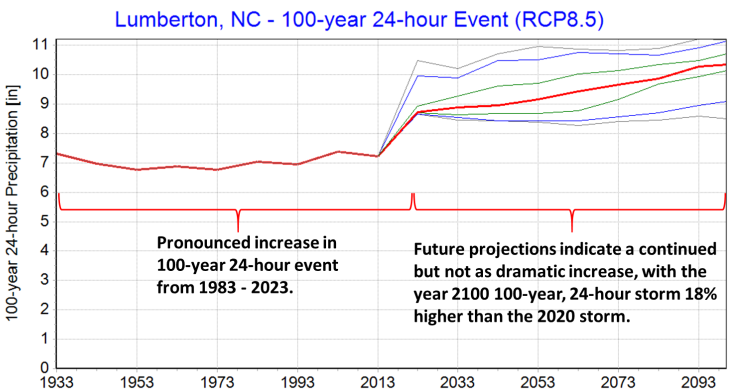
6,509 Road miles

473K buildings

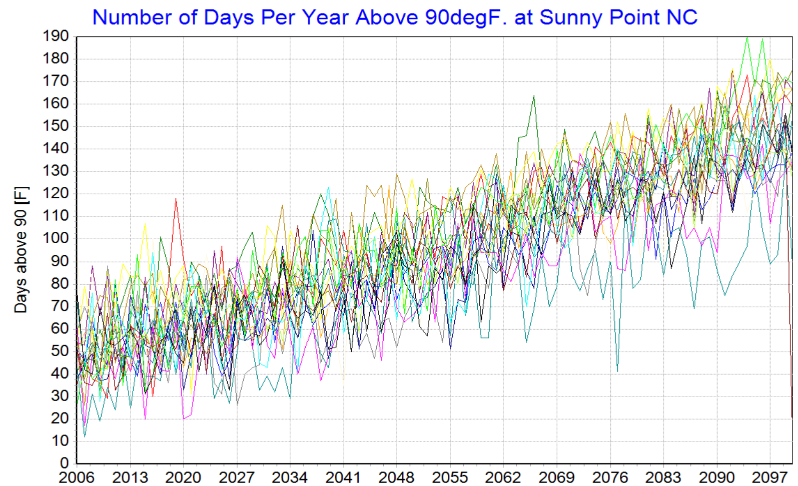
4,913 Rail crossings

US 74 Climate Stressors

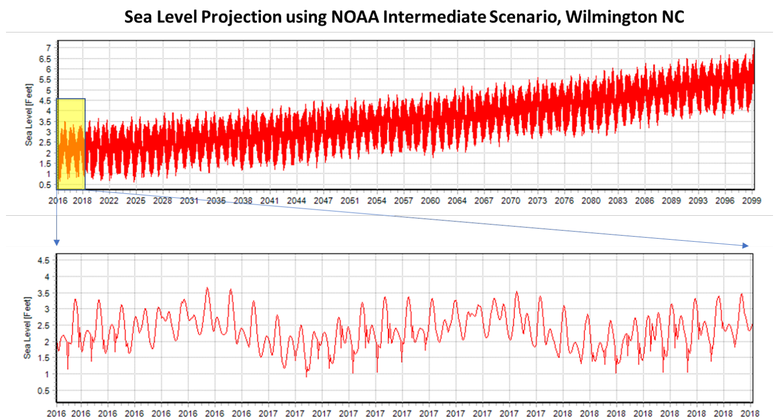
Rainfall



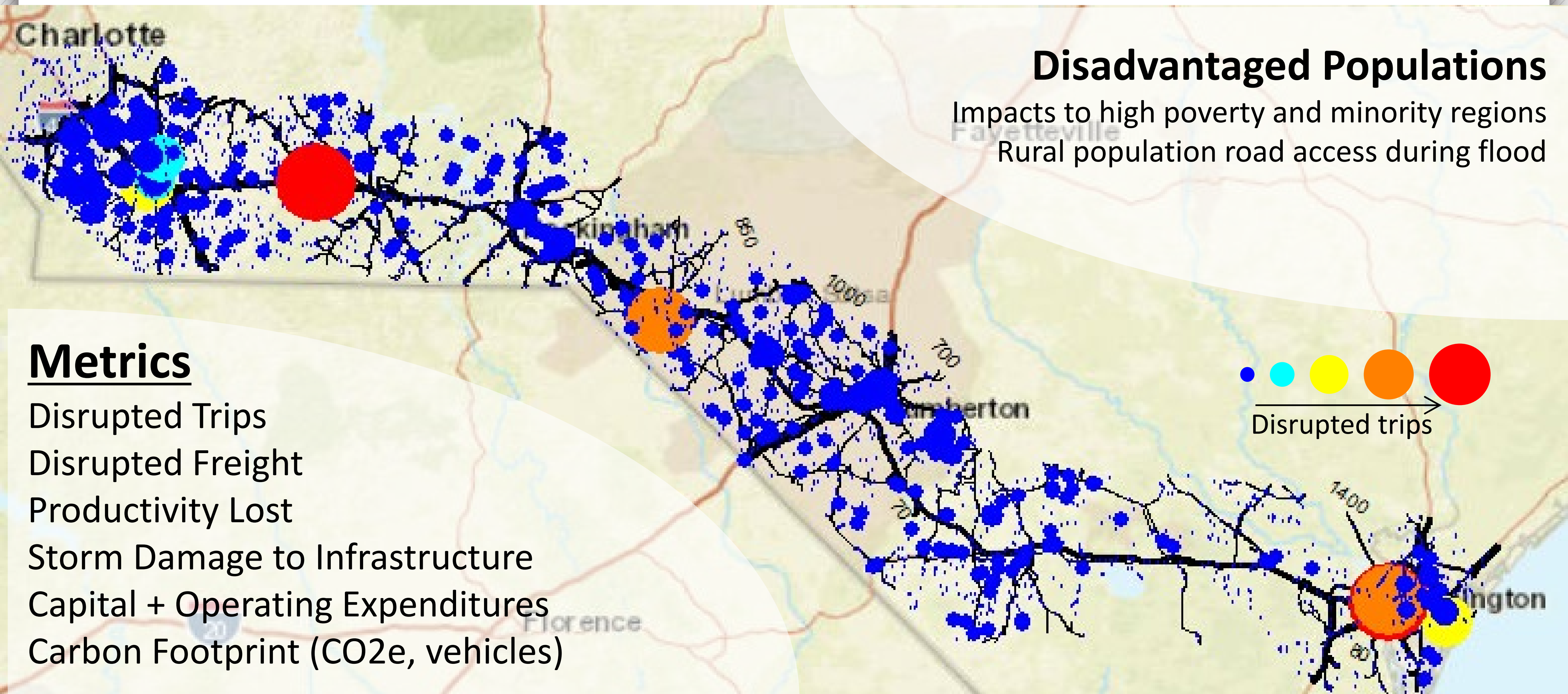
Temperature



Sea Level



US 74 Baseline Vulnerabilities



Disadvantaged Populations

Impacts to high poverty and minority regions
Rural population road access during flood

Metrics

Disrupted Trips
Disrupted Freight
Productivity Lost
Storm Damage to Infrastructure
Capital + Operating Expenditures
Carbon Footprint (CO_2e, vehicles)

US 74 Adaptation and Mitigation

Policy and Planning	Implement TSO solutions to provide efficient guidance and detour options	Adjust maintenance schedules to maximize preparedness	Increase real-time sensoring
General Infrastructure Improvement	Prioritize improvement to maximize resilience	Improve alternate routes	Avoid Response-driven capital improvement
Physical Climate Change Countermeasures	Elevate Roads	Harden roads	Harden rail crossings

Stormwater Initiatives and Support

- NPDES compliance
- Stormwater Management Project Requirements
- Stormwater Retrofits
- Research
- BMP Toolbox
- Section 401 Certification Negotiation Support
- Nature Based Solutions

Stormwater Management Plan (SMP) version 3.01

- Set stormwater treatment goals early in the project development process.
  - Preliminary stormwater management plan (pSMP)
    - Consists of the 1st two tabs in the SMP excel file (General Project Information, Waterbody Information)
- Version 3.01 released
  - Expanded the General Project Narrative Field
    - SELDM-Catalog results - (MORE TO COME!!!)
  - Additional BMPs added

SMP v3.00

Stormwater Management Plan (SMP) version 3.01

- Preliminary stormwater management plan (pSMP)
  - SELDM-Catalog Stochastic Empirical Loading and Dilution Model (SELDM) > USGS
      - National model
    - NC-SELDM > USGS & NCDOT
      - NC specific model
      - Complex with a significant learning curve
    - SELDM Catalog > USGS & NCDOT
      - User-friendly (Easily accessible input)
      - Project Scenarios pre-ran through the SELDM model
      - Simple Results = Stormwater Treatment Goals (per project sections)

N.C. DEPARTMENT OF TRANSPORTATION Hydraulics Unit

USGS

Nature Based Solutions - NC-24 Swansboro

- NFWF Grant awarded in partnership with NC Coastal Federation March 2020
- Protect ~1/2 mile of NC 24 near Swansboro
- Establish Tidal Marsh, Oyster Bed, and Riparian Upland Habitat
- Increased Resilience through Nature Based Design
- Design will protect for wave action and overtopping of roadway and bridge abutments.
- Future SLR modeling completed.
- Project is being coordinated with Division 3 and 2.
- Estimated Construction cost for 2 sites is approx. $3MM – Cost Share – SL 251

Research

- Predicting Roadway Washout Locations During Extreme Rainfall Events
- Compare NCDOT Bridge Scour Calculations to USGS SIR 2016-5121 South Carolina (SC) Scour Envelope Curves Results
- Evaluation of 2-D Hydrodynamic Models to Improve Scour Predictions and Countermeasures
- Future Precipitation for Resilient Design
- TPF-5 (461) - Task 7: Scour along Longitudinal Structures

Predicting Roadway Washout Locations During Extreme Rainfall Events

- 1177 crossing washouts occurred during Hurricanes Matthew and Florence
- Washouts also occur during localized flash flood events
- Overtopping and washouts pose a significant threat to human life
- Incidents are expected to become more common with climate change
- With the exception of larger bridges over major rivers, NC DOT's current response is reactionary

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

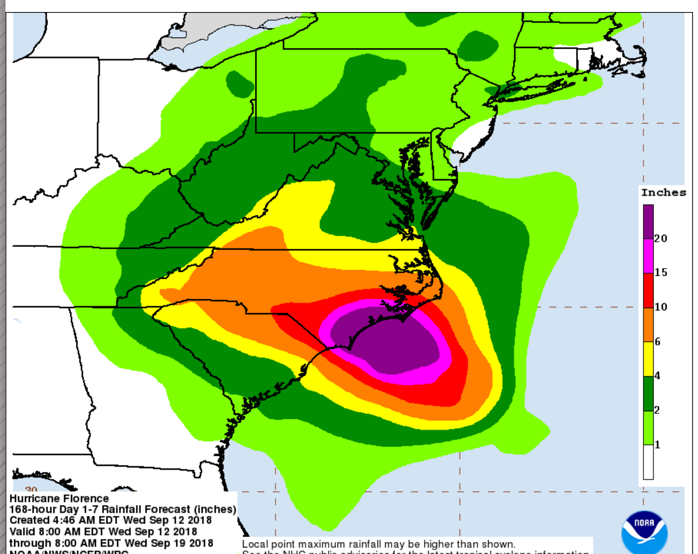
Sea Grant North Carolina

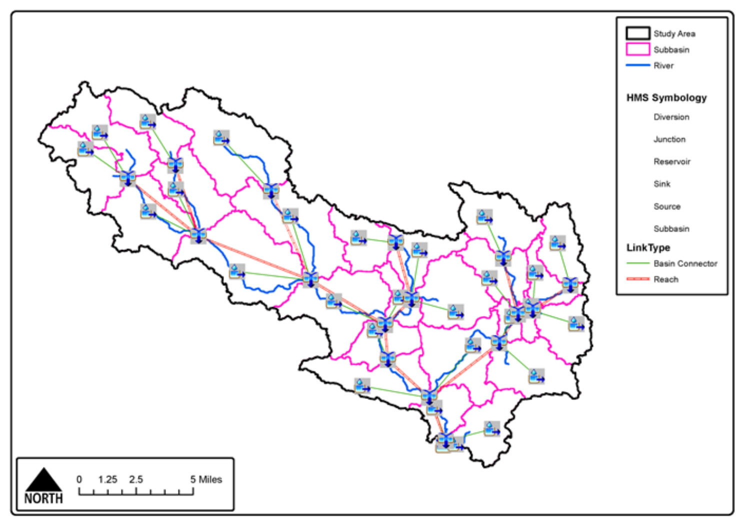
NC COOPERATIVE EXTENSION

NC STATE UNIVERSITY

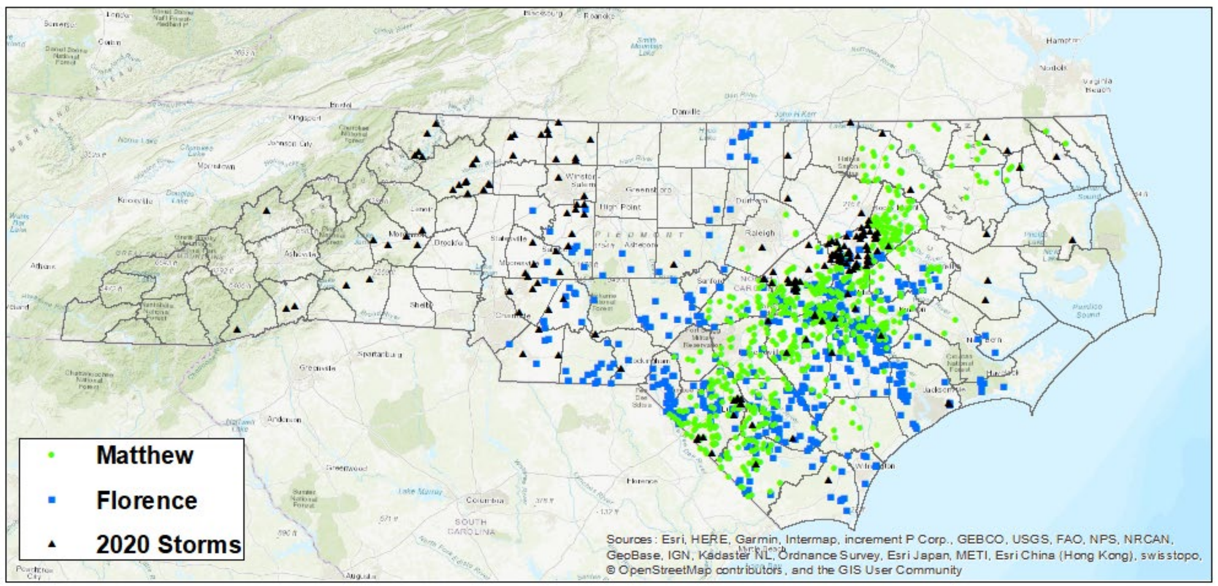
Goal: Predict culvert and bridge overtopping and potential washout based on forecasted rainfall depths

Rainfall Depths → Hydrolog y Model (Q) → Map of culvert locations and discharge values for each crossing's point of overtopping & predicted road washout





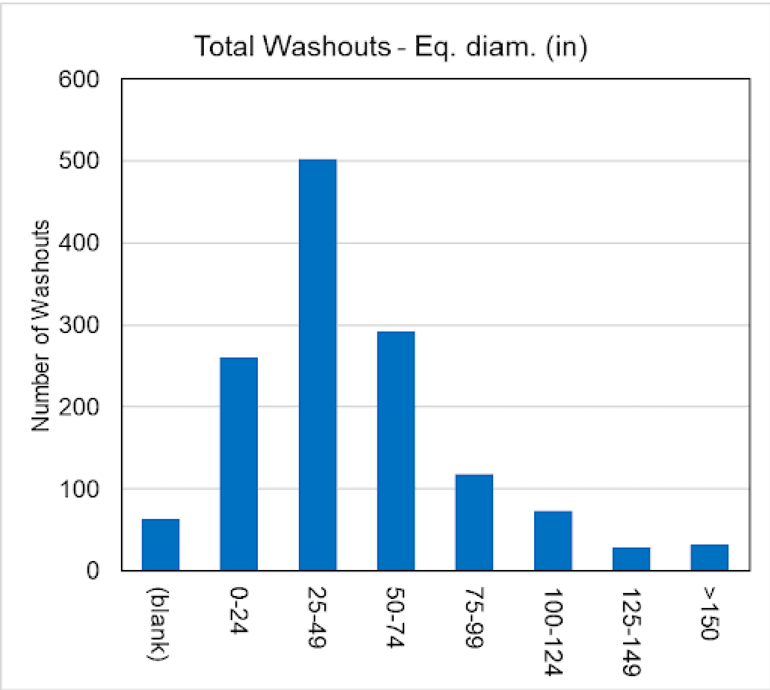
Study Process/Metrics:

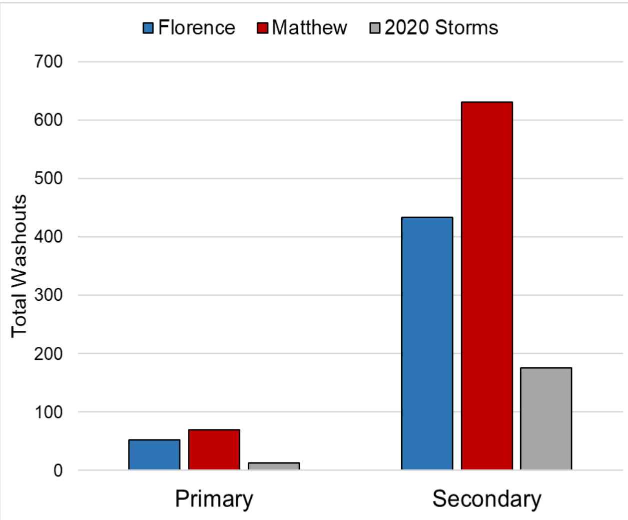


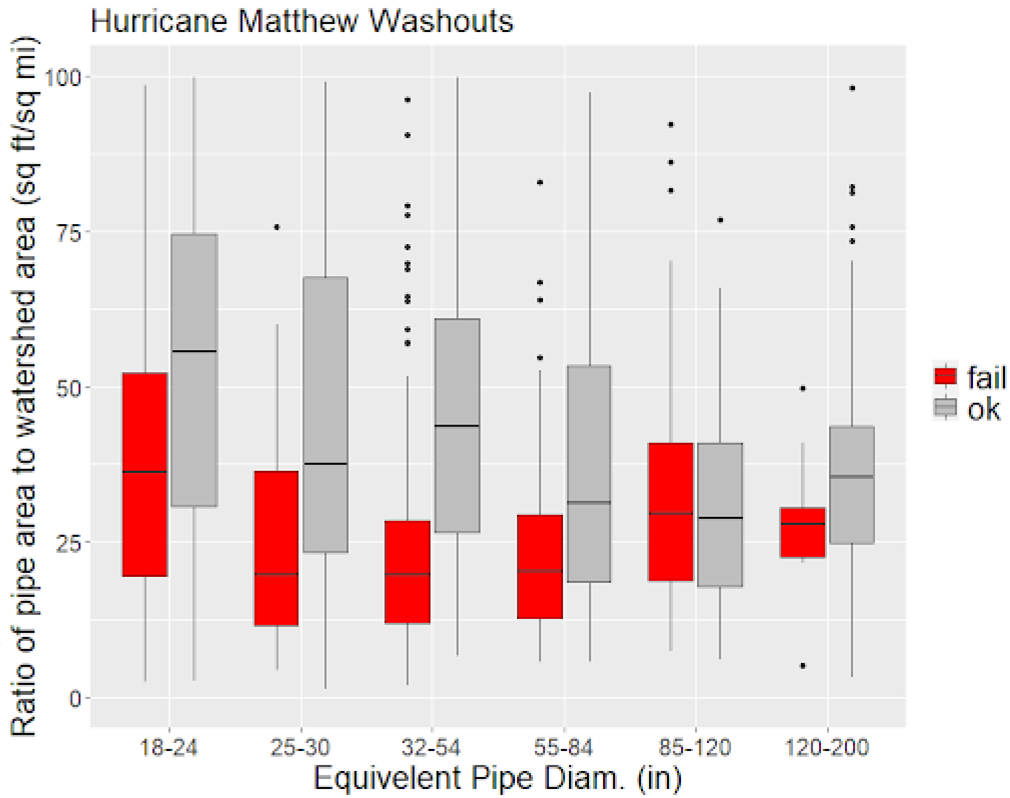
1. Characterize past washouts during extreme events using geospatial, statistical and machine learning tools to identify common factors
2. Develop watershed models that predict washout locations using future rainfall forecasts:
    1. Build watershed models for three case study watersheds
    2. Relate discharge to overtopping & washout risk for each crossing location
    3. Input gridded rainfall into watershed models
    4. Use washout prediction relationships to determine risk
    5. Display results on GIS map
3. Develop network of “resilient” travel routes

Preliminary Results

- Most washouts have occurred at smaller pipes (24 to 72 inch diameter) on secondary roads
- Washouts commonly occur where pipes are undersized (small flow area to watershed area)







NORTH CAROLINA
Department of Transportation

Compare NCDOT Bridge Scour Calculations to USGS SIR 2016-5121 South Carolina (SC) Scour Envelope Curves Results

Description

- ✓ **Guidance on applicability of "SC scour envelopes" to NCDOT bridge sites**
- ✓ **Propose various approaches to predict scour magnitude at bridges in NC**

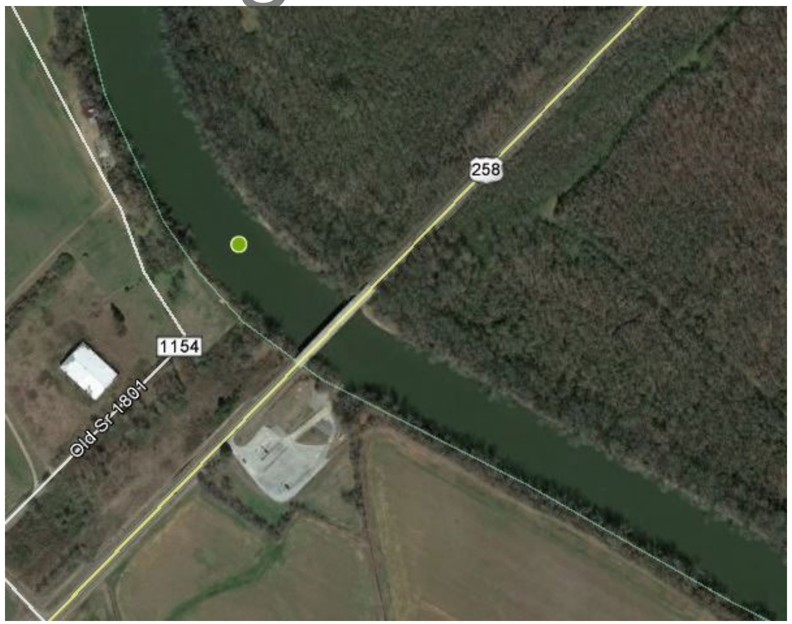
- **Under identical hydraulic and geometric conditions, different models yield vastly different magnitude of scour estimates, and can be conservative or unconservative**
- **Bridge design approach of super- and sub- structure needs to be consistent, therefore there is a need for scour estimation factors encompassing target reliability levels in concert with LRFD approach**

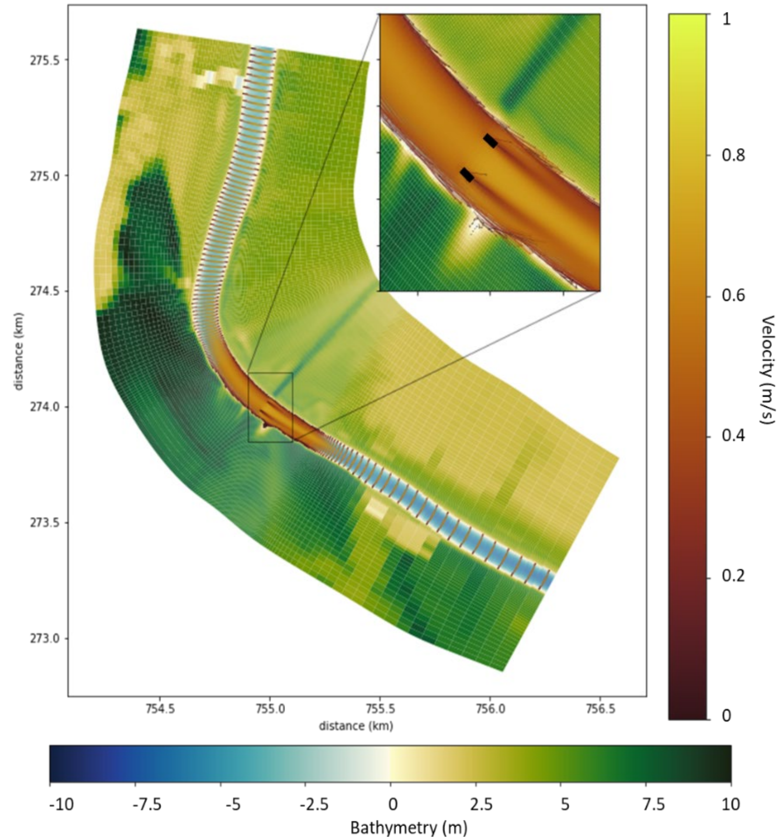
Yao, 2013

Goals

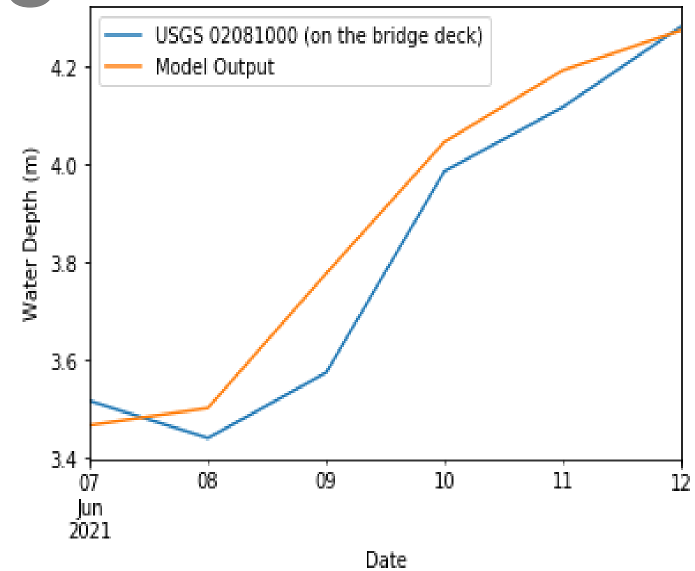
- Field Monitoring at Bridge Sites: Collect Data on Geometry, Bathymetry and Flow Conditions
- Delft 3D Numerical Modeling: Assess Impact of Key Flood Events with Various Return Periods
- Analytical Modeling: Comparison of Delft3D Model Predictions, Existing Simple Analytical Model Predictions, Field Observations, and SC Scour Envelope Prediction
- Synthesis of Field and Numerical and Analytical Modeling Results to Recommend Scour Assessment Approaches and Scour Factors Consistent with LRFD Concept

Example Results: Integration of Numerical Modeling and Field Data





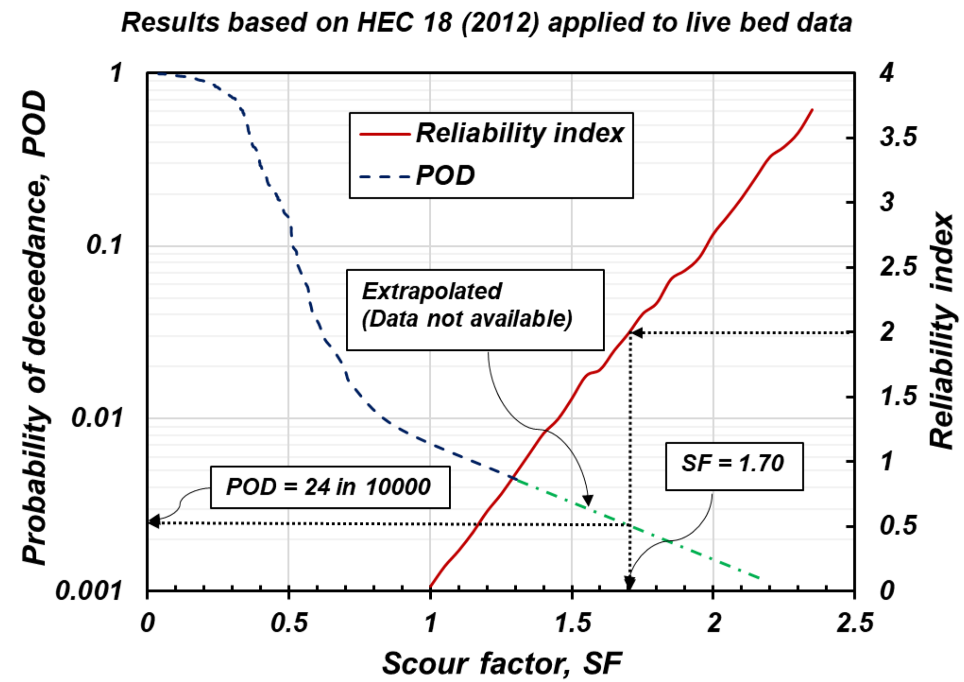
Delft FM Roanoke River spatial domain, mesh, and equilibrium bathymetry overlain by flow velocity, the black rectangles show the bridge piers locations in the model. The spatial domain consists of 33,927 elements and covers an area with a size of ~3 km x ~1.5 km.



Time series of water depth measured by USGS gage 2081000, located at the bridge (blue line) and modeled water levels (orange line).

Example Results: Application of Scour Factors

- Site conditions:
  - Pier diameter: 2 ft (Circular)
  - Pier skew: 0 degree
  - Upstream mean velocity: 2 ft/sec
  - Flow depth: 6 ft
  - D_{50}: 0.7 mm
- Analyses
  - Live bed condition
  - HEC 18-predicted scour depth= *2.8 ft*
  - SC envelope predicted scour depth= *5.6 ft*
  - Target reliability index, β_T= *2*
  - Corresponding scour factor: *1.70*
  - Scour corresponding to "$\beta_T = 2$" is *4.8 ft*



Benefit: When a deterministic model is used, the users do not have the knowledge of associated reliability of scour estimates. Yet with the LRFD the foundation and the bridge are designed to specific reliability level. Using the proposed approach, scour depth can be estimated based on a target reliability index in concert with the reliability level of the sub- and super- structure.

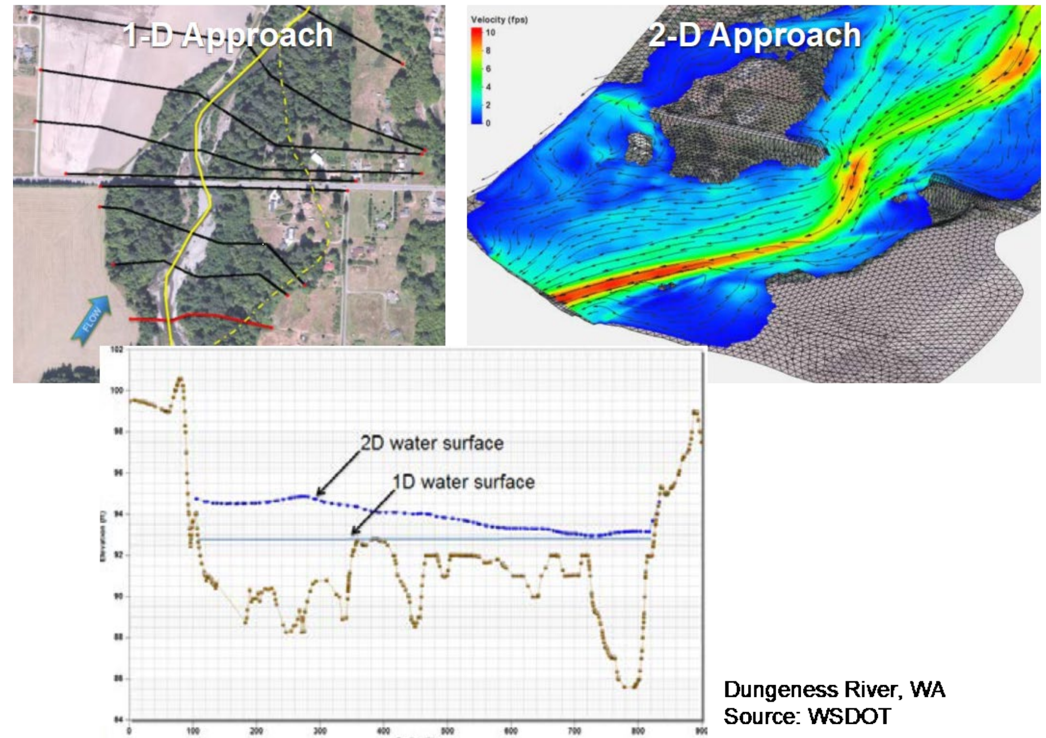
NORTH CAROLINA
Department of Transportation

Evaluation of 2-D Hydrodynamic Models to Improve Scour Predictions and Countermeasures

Description

- This project seeks to examine the capabilities of 2-D hydraulic and sediment transport numerical models for improving bridge scour prediction.

Field Monitoring Using Fiber-Optics Distributed Temperature Sensing (FO-DTS)



Dungeness River, WA
Source: WSDOT

Numerical Simulations Using 2D Hydro-Morphodynamic Modeling

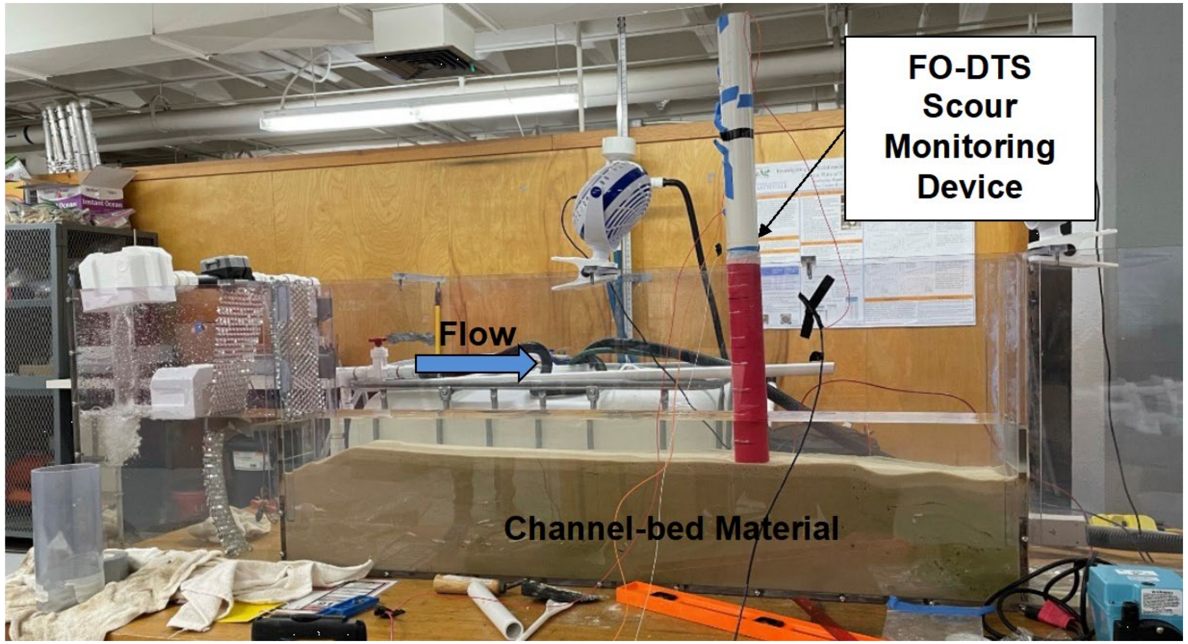
Objectives

- To construct and test the ability of a scour monitoring device based on FO-DTS to locate and track the sediment-water interface.
- To compare the performance of 1-D numerical models to that of 2-D numerical models when predicting flow and sediment transport at bridge crossings.
- To develop recommendations for predicting scour depths and for evaluating countermeasures for scour mitigation at bridge crossings using 2-D numerical models.

Methodology

FO-DTS Scour Monitoring

Device & Experimental Setup:



- *Device: **Resolution = 1.2-2.4 mm**; H = 60 cm; D= 5 cm.*
- *Flume: L = 2.4 m; W = 0.2 m; H = 0.6 m.*
- *Channel-bed material is sand with D_{50} = 0.15 mm.*
- *Testing focused on the effect of flow velocity on the device's ability to track the water-sediment interface.*

Hydro-Morphodynamic Modeling

Study Sites & Numerical Models:

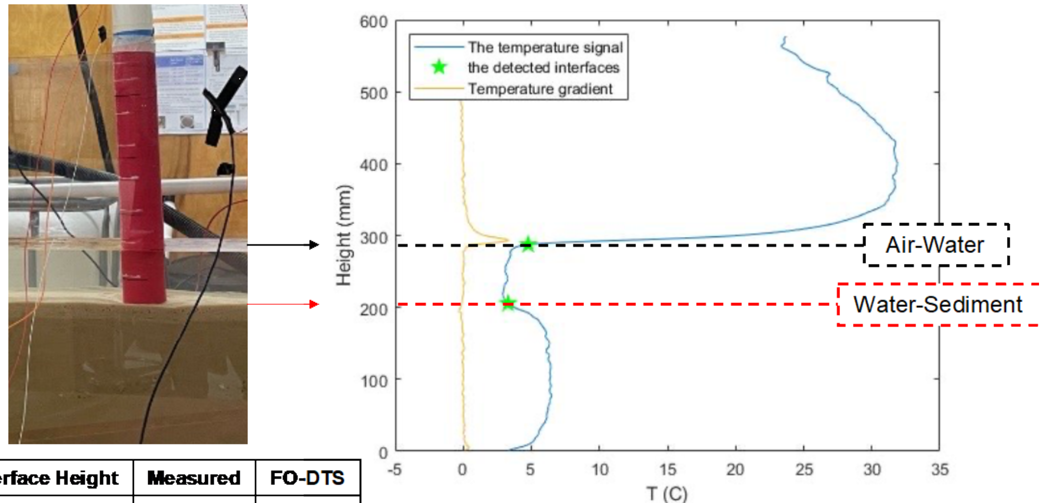
- *Four bridge crossings within the Piedmont and Coastal Regions with varying physical, flow, and geomorphic features.*

- *Numerical Models:*
  - *USACE HEC-RAS 1D (cross-sectionally averaged).*
  - *USBR SHR-2D (depth-averaged).*
- *Simulations focused on the effect of site characteristics on flow field characterization and scour predictions.*

Results

FO-DTS Scour Monitoring

Laboratory Experiments:



Interface Height	Measured	FO-DTS
Air-Water	330 mm	290 mm
Water-Sediment	215 mm	205 mm

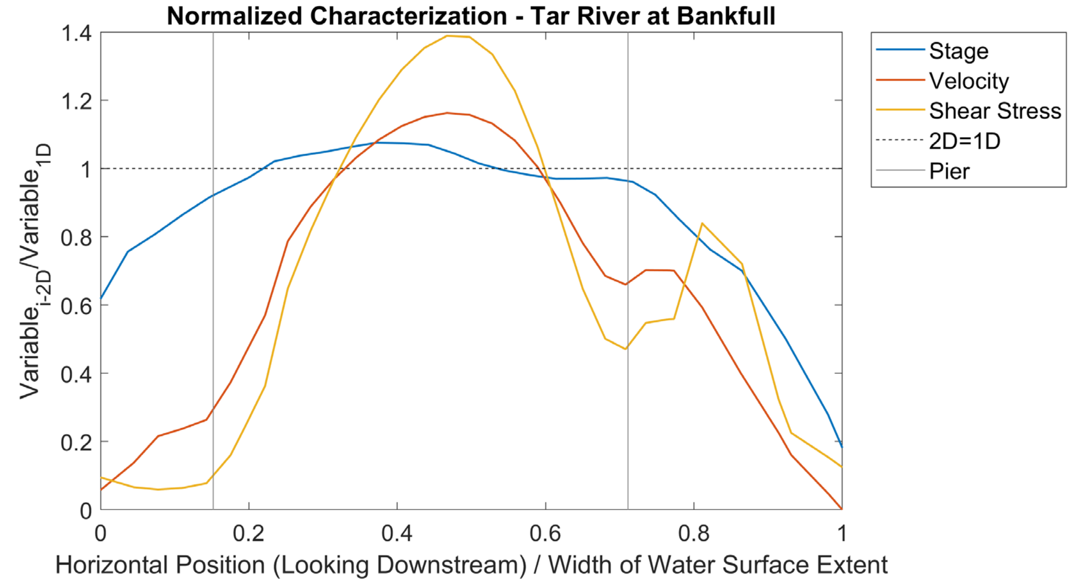
FO-DTS device accurately tracked the location of the water-sediment interface for varying flow velocities.

In progress:

- *Event-based bridge scour measurements in the field using the FO-DTS monitoring device.*

Hydro-Morphodynamic Modeling

Flow Field Characterization:



2D modeling captured spatial variability of flow and sediment transport variables along the channel

In progress:

- *Implications of flow field characterization (1D vs. 2D) for bridge scour prediction.*

Contacts

Highway Floodplain Program (Statewide)
Brian Radakovic, PE
bmradakovic@ncdot.gov 919-707-6747

Highway Stormwater Program (Statewide)
Andrew McDaniel, PE
ahmcdaniel@ncdot.gov 919-707-6737

Design Support East (Div 1-6, 8)
Charles Smith, PE
crsmith1@ncdot.gov 919-707-6716

Operations Support East (Div 1-9)
Galen Cail, PE
gcail@ncdot.gov 919-707-6711

Design Support West (Div 7, 9-14)
Brook Anderson, PE
beanderson1@ncdot.gov 919-707-6706

Operations Support West (Div 10-14)
Jonathan Moore, PE
jlmoore6@ncdot.gov 919-707-6738

Thank you, Hydraulics!

N.C. DEPARTMENT OF TRANSPORTATION
Hydraulics Unit